Options Trading Activity and the Efficiency of Corporate Investment

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Abstract

We examine the relation of active options market trading and the (in)efficiency of corporate investment in terms of deviation from optimal investment levels. Past research considers the volume of options trading as contributing to firms' informational efficiency. Investment efficiency is partly driven by information asymmetries between firm managers and capital providers, aggravating moral hazard concerns. We test whether the enhancement in firms' information environment associated with higher volume of options trading activity is positively related to optimizing investment at the firm level. Our results indicate that the volume of options trading by firms is positively and significantly associated with firm-level investment efficiency. This relation is associated with the enhancement in the firms' information environment stemming from active options trading. Overall, our findings suggest that the managerial skills associated with active trading in derivatives markets also benefit firms' investment decisions through enhancing the optimal allocation of firm resources and investment efficiency.

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Keywords: Option trading activity, investment efficiency, under- or over-investment, information asymmetry, agency costs.

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1. Introduction

In this paper, we examine the association between options trading activity and the efficiency of corporate investment in terms of deviation from optimal investment levels. Although research on the effects of options trading activity has mainly focused on stock market outcomes (Chen et al., 2020), recent work provides insights into its effects on corporate decision-making and firm policies (Gao, 2010; Cao et al., 2020b; Chen et al., 2020; Blanco and Wehrheim, 2017). This work shows that options trading facilitates the transfer of information from the options to the stock market, enhancing price discovery and improving the informational efficiency and overall information environment (Chakravarty et al., 2004; Pan and Poteshman, 2006; Ge et al., 2016; Blanco and Wehrheim, 2017; Ali et al., 2020; Chen et al., 2020). Options trading stimulates information production and acquisition leading to more informed trades (Cao et al., 2020b), reduces the cost of capital and information asymmetries between firm managers and outsiders (Ross, 1976; Kumar et al., 1998; Pan and Poteshman, 2006; Naiker et al., 2013; Hu, 2014; Blanco and Wehrheim, 2017; Chen et al., 2020) and increases firm value (Roll et al., 2009). Options trading also increases the participation rate of informed traders (Chakravarty et al., 2004; Hu, 2018), helping make markets more complete. These benefits accrue mainly to firms with options trading activity, and increase with higher volume of options trading (Chen et al., 2020).

In theory, in frictionless markets firms make their financing and investment decisions independently (Modigliani and Miller, 1958), undertaking projects with positive net present value (Modigliani and Miller, 1958; Hayashi, 1982; Biddle et al., 2009). With capital market frictions, as a result of conflicts of interest arising between firm insiders and outsiders and financing constraints (Jensen and Meckling, 1976; Myers and Majluf, 1984), firms deviate from optimal levels of investment by over- or under-investing. Prior literature has identified information asymmetries, adverse selection and moral hazard frictions as triggering factors for sub-optimal levels of investing (e.g. Biddle et al., 2009; Jung et al., 2014, among others). This research has suggested that investment inefficiency in terms of deviations from optimal levels of investment can be mitigated by enhancing firms' informational efficiency, which should further reduce moral hazard concerns through more effective monitoring by shareholders and other stakeholders (Cheng et al., 2013; Chen et al., 2017b).

Given this context, this paper examines whether the volume of options trading, a factor that reduces firm-level information asymmetry and differential access to firm-specific information by outsiders compared to the firm's management, is associated with improvement in the efficiency of investments made by the firm. Investment efficiency, defined as minimal deviation from optimal investment levels, is influenced by firm-level informational efficiency and by discrepancies in the amount of investment-related information between firm insiders and outsiders (e.g. Biddle et al., 2009, Chen et al., 2017a, 2017b). We expect that a higher intensity or volume of options trading activity, by improving the firm's information environment should have a positive association with the efficiency of corporate investment reducing deviations from optimal investment levels.

Levels of firm investment are often suboptimal due to capital market frictions with deviations from optimal levels involving either over- or under-investment. Two types of frictions that commonly trigger inefficient investment relate to information asymmetries and agency problems (Biddle and Hilary, 2006; Biddle et al., 2009; Benlemlih and Bitar, 2018). First, managers may deviate from optimal levels of investment when their private interests deviate from those of shareholders because of adverse selection (Biddle et al., 2009). As managers possess private information about the firm's value, they may time the issuance of capital when the firm is overpriced (Biddle et al., 2009; Chen et al., 2017b). Because of the information asymmetry between managers and investors, outside capital providers will naturally be suspicious of this type of behavior and discount new issues through an increase in the cost of funding (Biddle et al., 2009; Chen et al., 2017a; Ward et al., 2020), a classic "lemons problem." This may trigger either over- or under-investment depending on whether managers make excess capital investments or refuse to issue capital at discounted prices, respectively (Myers, 1984; Myers and Majluf, 1984; Biddle et al., 2009; Chen et al., 2017b). Second, in the presence of agency conflicts and moral hazard, the deviating incentives between managers and shareholders may exacerbate over- or under-investment depending on the availability of capital (Biddle et al., 2009). Managers may over- or under-invest because of their own private interests, e.g., due to self-gratification or empire building, or when they choose not to exert the time and effort necessary to identify value-enhancing projects. For example, they may under-invest living the "quiet life" (Bertrand and Mullainathan, 2003; Chen et al., 2017b). Investors can track this behavior ex-ante and ration the supply of capital, triggering under-investment ex-post (Biddle et al., 2009).

At the same time, trading activity in the options market increases the informational efficiency of stock prices (Pan and Poteshman 2006; Cremers and Weinbaum 2010, Chen et al., 2020), reduces informed trading (Hu, 2018) and helps correct stock overvaluation (Diamond and Verrecchia, 1987). Furthermore, if informed investors trade more frequently in options rather than the stock market, information may be transferred to the stock market thus facilitating price discovery (Cremers and Weinbaum, 2010; Jin et al., 2012; Johnson and So, 2012; Chen et al., 2020). As stock prices become more informative, information asymmetry between firm insiders and outside investors is reduced (Chen et al., 2020). For this reason, the volume of options trading should improve the firm's informational efficiency and reduce information asymmetries between managers and the providers of capital.

Both information asymmetry and moral hazard concerns lead to differential access to information between firm managers and the suppliers of capital, preventing outsiders to efficiently assess and predict a firm's prospects and impede the monitoring exerted by outsiders. The volume of options trading may reflect informed trading based on fundamentals, volatility trading or uninformed trading, while options trading changes affect the information environment of firms by enhancing stock price informativeness (Cao et al., 2020a). For these reasons, we examine whether the enhancement of firms' information environment associated with higher volumes of options trading is positively related with optimizing investment resource allocation at the firm level. We, thus, hypothesize that the intensity of trading in options markets should be positively associated with the efficiency of firm-level corporate investment.

We examine this research question focusing on US firms with traded options in Optionmetrics during the 1996-2019 period and find that the volume of options trading (in dollars or in units) is positively associated with firm-level investment efficiency. We measure investment inefficiency as firm-specific residuals from a model predicting the level of investment in growth opportunities based on sales growth as per Biddle et al. (2009). We additionally extend the baseline model of Biddle et al. (2009) to better account for growth opportunities in line with growth option variables and evidence in Trigeorgis and Lambertides (2014). We find that our results are stronger for under-investment (compared to over-investment) and are mostly driven by non-capital expenditure (NonCapex) mainly consisting of R&D investments and acquisitions that mostly involve growth options, rather than capital expenditure (Capex) investment mostly focused on assets-in-place (AIP). These results support the notion that a higher volume of options trading is mitigating information asymmetry and moral hazard concerns for external capital providers, with a stronger effect on mitigating under-investment which is driven by this type of concerns. At the same time, we find that options volume mainly has an alleviating effect on investment inefficiency when investment outcomes are more uncertain and involve more growth options, as in the case of NonCapex relative to more concrete and tangible Capex investments, providing support for the information enriching role of options trading. These results are robust to using alternative models of investment to measure deviations from optimal levels of investment and investment inefficiency and when using ex ante firm-specific characteristics such as R&D, cash levels and leverage to identify investment (in)efficiency (Biddle et al., 2009; Cheng et al., 2013; Chen et al., 2017b). Results are also robust to alternative measures of options volume activity: results remain strong when e.g. options volume is based on the number of contracts rather than their dollar value, when call options volume and put options volume are considered separately, or when we measure option market activity through delta-weighted options volumes, as in Lakonishok et al. (2007).

Endogeneity remains a concern as the production of corporate information stems from factors which are unobservable but may correlate with the volume of options trading. We cannot preclude the possibility that options volume is endogenously determined by the efficiency of firm investment, or that both options volume and efficient investing are simultaneously (co)determined by the effectiveness of firms' information environment or by managerial skills linked to options awareness.

We use several methods to mitigate potential endogeneity concerns. First, following Roll et al. (2009) and subsequent studies using their methodology (e.g., Blanco and Werheim, 2017; Cao et al., 2020a; Cao et al., 2020b, Chen et al., 2020), we apply a two-stage generalized method of moments (GMM) estimation and use option moneyness and open interest as instrumental variables (IVs). Our results remain strong using the GMM estimations with these two variables as instruments, as well as when using alternative ways of measuring investment efficiency.

We also employ propensity score matching (PSM) procedures, in which our treatment firms have high volumes of options trading (above industry-year median volume) with our control firms being otherwise comparable firms with low volumes of options trading (below industry-year median options volume). Our study hypothesizes that the intensity of options trading activity (rather than mere options market listing per se) should improve efficient investment. The average treatment effect between the two groups of firms indicates lower investment inefficiency for firms with higher vs. lower options trading volumes. Furthermore, we re-estimate our baseline model specification for firms with high options trading volume and propensity score-matched low volume counterparts, confirming that our findings hold for our treatment and control-matched samples. We conclude that our evidence on options trading volume being positively related to investment efficiency is not driven by endogenous firm characteristics. Overall, the results of the two-stage IV GMM estimation and the PSM analysis confirm the predicted positive association of options trading with firm investment efficiency.

We further investigate the underlying mechanisms that may drive our results. Regarding the efficacy of external monitoring, options trading should improve firms' information environment and thus help alleviate adverse selection and moral hazard problems that trigger investment inefficiency. The improved information environment associated with options trading may help enhance the efficiency of alternative governance mechanisms, reducing managerial entrenchment. However, when external monitoring performs a similar role in reducing investment inefficiency as options trading activity, our baseline result should be less strong as the quality of such monitoring and information-enhancing mechanisms increase.

When the strength of monitoring and information-enriching mechanisms increase, as measured by the size of institutional block holdings and the existence of credit ratings for firms' long-term debt, the positive association of options trading with investment efficiency is weaker. Specifically, our main result is weaker for firms with higher-than-average strength of institutional monitoring and for firms without a credit rating issued on their debt. This suggests options trading activity may substitute for or work in the same direction as the aforementioned factors and is thus negatively related with investment inefficiency as these factors allow more accurate inference of firms' investment opportunities.

We also perform a number of supplementary analyses to corroborate the above results. Our main finding on a positive association between options trading volume and enhanced investment efficiency holds when unexpected investment (a signal of poor performance, see Chen et al., 2017b) is higher, suggesting that trading volume predominantly improves the information environment for poorly-performing firms that need this the most. Further, our results hold primarily for firms with lower-than-median business and geographical segments, an indication that options trading volume plays an information enriching role especially when the degree of firm complexity is low. However, the information enriching effect of options trading volume may not work efficiently for very high levels of firm complexity. Finally, given recent evidence on direct interactions among different types of derivatives related to the same firm (Cao et al., 2019), we find that our results are driven mainly by firms which do not trade in other derivatives markets such as the CDS market, with repercussions about the substituting role that trading in multiple derivative markets can play in enhancing firm informational efficiency. Overall, this evidence provides support for the prediction that trading in derivative markets is positively associated with enhancement in the optimal allocation of corporate resources and more efficient firm investment. This effect is more pronounced when other mechanisms that enhance the firm's business information environment are weaker. This is consistent with our evidence that the positive association of options trading activity with investment efficiency is mainly concentrated on investment that is inherently uncertain in nature and primarily involves growth options emanating from NonCapex-type investments such as R&D and acquisitions.

Our study takes the effect of options trading on price informativeness as given (Blanco and Wehrheim, 2017) and builds on research concerning the effect of information production on corporate investment decisions with a focus on the efficiency of firm-level investment choices. Our evidence builds on previous findings by Blanco and Wehrheim (2017) who examine the effect of price informativeness on corporate investment decisions related to innovation. Our focus, however, is on the relation of information production associated with active options trading with important corporate outcomes inherently driven by the efficiency of the information environment of firms and the effectiveness of monitoring exerted by the external providers of capital.

Our study follows a recent stream of research examining whether financial markets affect corporate decision-making or whether they are simply a sideshow with no real economic consequences (Cao et al., 2020b). This literature considers the interaction among information production or price informativeness and corporate investment decision-making (Blanco and Wehrheim, 2017). Price informativeness can work towards disciplining managers, providing them with incentives for optimizing firm-value (Holmström and Tirole, 1993; Faure-Grimaud and Gromb, 2004); at the same time, information incorporated in stock prices can help better guide firms' investment decisions given that firm managers are compensated based on future stock market performance (Dow and Gorton, 1997).[1] We show that the volume of options trading is positively associated with attaining more optimal levels of investment at the firm level and that active options trading helps alleviate concerns related to information asymmetry and moral hazard. Our findings provide insight into the positive association between enhanced informational efficiency associated with options trading and firm-level performance outcomes associated with more efficient investing.

The rest of the study is structured as follows. Section 2 provides a brief review of related literature and develops our main research hypotheses. Section 3 describes sample selection and the basic methodology used for measuring (in)efficient investment and examining its association with options trading intensity. Section 4 discusses our main findings, endogeneity tests, and the effect of external monitoring on the association between trading activity and investment efficiency. Section 5 reports supplementary analyses and specific contexts where our results are more pronounced and various robustness controls. Section 6 concludes the study.

2. Literature review and hypothesis development

2.1 Literature review

2.1.1 Firm-level investment (in)efficiency

The neoclassical theory of investment posits that, subject to adjustment costs, firms achieve their optimal levels of investment when the marginal benefit of investment equals the marginal cost (Hayashi, 1982; Biddle et al., 2009; Ward et al., 2020). Firms deviate from optimal levels of investment due to capital market frictions. Previous literature has identified two types of frictions that may trigger inefficient investment, information asymmetry and agency problems (Biddle and Hilary, 2006; Biddle et al., 2009; Cheng et al., 2013; Chen et al., 2017b; Benlemlih and Bitar, 2018; Cook et al., 2019).

First, managers may deviate from optimal levels of investment when their private interests deviate from those of firm shareholders because of adverse selection (Biddle et al., 2009). Information asymmetries between managers and investors can have an adverse effect on project selection and the cost of raising capital (Myers, 1984; Myers and Majluf, 1984; Benlemlih and Bitar, 2018). Managers possess superior private information about the firm's true value compared to outside investors so they may time the market, issuing capital when the firm is overpriced and potentially over-invest the proceeds (Biddle et al., 2009; Chen et al., 2017b; Cook et al., 2019). Because of the information asymmetry between managers and investors, even if managers act in the shareholders' best interests, outside capital providers who are subject to informational disadvantages may suspect this type of behavior and discount new equity issues through an increase in the cost of funding (Biddle et al., 2009; Chen et al., 2017a; Ward et al., 2020). This results in a "lemons problem" where capital

[1] For a detailed review of this literature, see Blanco and Wehrheim (2017: 101).

providers are unable to distinguish between good vs. not so good corporate borrowers, inducing limited levels of investment. This can result in over-investment if managers make excess capital investments or it may trigger under-investment if managers decide to protect the interests of existing shareholders and forego profitable investment opportunities, refusing to issue capital at discounted prices (Myers, 1984; Myers and Majluf, 1984; Biddle et al., 2009; Chen et al., 201b7; Gao and Sidhu, 2018; Benlemlih and Bitar, 2018). This can occur when investors respond to informational disadvantages by raising the cost of providing funding (Jung et al., 2014; Cook et al., 2019). Lambert et al. (2012) and Bhattacharya et al. (2011) suggest providing more information to investors helps reduce firms' cost of capital (Chen et al., 2017b).

Second, according to agency theory and moral hazard, the misalignment between managerial incentives and shareholders' interests may also result in deviations from optimal levels of investment (Biddle et al., 2009; Chen et al., 2017b). In the presence of plentiful resources to invest, managers may over-invest because of their own private objectives, such as self-gratification, by growing the firm beyond its optimal size through empire building because of management entrenchment (Jensen, 1986; Blanchard et al., 1994; Chen et al., 2017b) or due to managerial hubris as managers overestimate their own abilities to select profitable investment opportunities (Chen et al., 2017b). Managers may also over-invest because of differences in risk preferences vis-à-vis shareholders (Holmström, 1999). Countering this, managers may under-invest if they choose not to dedicate the time and effort necessary to efficiently identify positive net present value projects, preferring to live the "quiet life" (Hart, 1983; Bertrand and Mullainathan, 2003). However, if capital providers identify this behavior ex-ante they may constrain the supply of capital leading to ex-post under-investment (Lambert et al., 2007; Biddle et al., 2009).

In both cases above, the result is the same leading to suboptimal or inefficient levels of corporate investment. The sensitivity of investment to stock prices is determined by the extent of the firms' information asymmetries and agency problems (Chen et al., 2007; Jiang et al., 2011). Nevertheless, any adverse effects of information asymmetry and moral hazard on investment efficiency can be mitigated through improvements in firms' information environment and the efficiency of external monitoring (Chen et al., 2017b).

2.1.2 Options trading activity

Under perfect markets, options are redundant assets with their payoffs replicated by taking positions in stock and bonds (Black and Scholes, 1973; Merton, 1973). However, in the presence of market frictions options are not redundant (Ross, 1976; Figlewski, 1989; Chen et al., 2020). Options improve efficiency in incomplete markets by expanding investors' investment opportunity set (Ross, 1976; Hakansson, 1978). Cross-market information transfer also occurs across options and stock markets (Chen et al., 2020) with options playing a useful role in stock price discovery (Merton 1976;

Klemkosky and Resnick 1979; Cremers and Weinbaum 2010). In informationally complete markets, option prices cannot lead stock prices (Du, 2019) and the price of options is a function of the price of the underlying stock (Hull, 2003). Significant empirical research has examined the information transmission from the options market to stock prices and whether the options market leads the stock market. Chacravaty et al. (2004) show that the options market contributes to stock price discovery and that option markets are more informative when the options volume is higher.[2] Related research has used information extracted from options to predict stock returns (indicatively, Amin and Lee, 1997; Easley et al., 1998; Cao et al., 2005; Cremers and Winbaum, 2010; Pan and Poteshman, 2006; Xing et al., 2010; Johnson and So, 2012).

As options trading has become more prevalent in recent years (Du, 2019), the options market has become the preferred market for informed market participants. Options trading is popular as it is easier and less costly for investors in firms with tradable options to diversify their portfolios via hedging. Options inherently involve low cost and high leverage, being preferred securities to trade for informed investors with private information (Black, 1975). They are quite attractive for informed traders as multiple contracts cannot be readily processed by uninformed market participants (Easley et al., 1998).

Recent research has also focused on the effect of options trading intensity on corporate decision-making. Gao (2010) observes that CEOs of firms with active options trading have higher pay-for-performance sensitivity and higher sensitivity of CEO wealth to stock return volatility. Blanco and Wehrheim (2017) find that options trading volume positively relates to firm innovation activities. This effect is achieved via increases in informational efficiency and improved external monitoring for firms with high options trading volumes. Similar findings are reported by Hsu et al. (2019) regarding options trading promoting brand innovation as measured by trademark data. Concurrently, options positively associate with firm value with their valuation benefits depending on trading activity (Roll et al., 2009). More recently, options trading is shown to negatively associate with the likelihood and frequency of management earnings forecasts (Cao et al., 2020a) and positively relate to firms' ability to issue public debt and rely less on bank debt (Cao et al., 2020b). In these cases, options trading goes hand in hand with increased firm-level informational efficiency, along with reduced cost of monitoring by outsiders. These positive effects of options trading activity are capitalised by firms in the form of outcomes that are negatively affected by firm-level informational obscurity.

As a whole, trading in options markets helps reduce information asymmetry between managers and outside investors (Chen et al., 2020), stimulates information production and improves the overall price efficiency for firms (Kumar et al., 1998; Ali et al., 2020). Price efficiency improves as options

[2] Muravyev et al. (2013) provide some conflicting evidence showing that option quotes do not incorporate economically significant information about future stock prices beyond the information already reflected in current stock prices.

trading helps cover a wider range of contingencies in the market (Ross, 1976; Blanco and Wehrheim, 2017; Du, 2019). Moreover, active options markets alter incentives for market participants to acquire private information while trading based on this information increases the accuracy of market pricing (Cao, 1999; Chakravarty et al., 2004; Pan and Poteshman, 2006; Hu, 2014), which is particularly relevant for long-term investments (Blanco and Wehrheim, 2017). Options trading also reduces firm-level information asymmetry by transferring private information from options traders to the stock market (Chen et al., 2020), thus facilitating price discovery in stock markets and enhancing the informational efficiency of stock prices (Pan and Poteshman 2006; Chakravarty et al., 2004; Ge et al., 2016; Du, 2019). This is because when informed investors trade in the options market, information may be transferred from that market to the stock market, with favorable repercussions about price discovery in the latter (Cremers and Weinbaum, 2010; Jin et al., 2012; Johnson and So, 2012). In this way, more efficient stock price discovery arising from options trading helps reduce information asymmetries between firm insiders and outside investors (Chen et al., 2020).

Options trading may also stimulate the very production of information, as investors have the incentive to procure more information about firms in the presence of higher trading volumes (Cao, 1999; Du, 2019). As option investors actively search to acquire more information, they are also more likely to access information hidden by managers (Cao et al., 2020b). If investors search and acquire more information when options trading activities increase, then managers may also be more likely to release more information (Chen et al., 2020).[3] Options listings have also been shown to improve stock price liquidity, and reduce firms' implied cost of capital (Naiker et al., 2013). Finally, options trading can facilitate a more efficient allocation of firm investment resources. Options trading volumes support higher market values and improve this resource allocation, as well as leading to increases in the sensitivity of investment to stock prices (Roll et al., 2009). In effect, options trading contributes to information production useful for managers in making better investment decisions (Cao et al., 2020b).

2.2 Hypothesis development

We aim to extend the above research testing whether options trading activity is positively associated with a more efficient allocation of firm-level investment resources. This is the first study to examine the association of options trading activity with more efficient firm-level investing (defined as deviation from optimal levels of firm investment). Our findings aim to complement evidence obtained by previous research consistent with options volumes improving resource allocation via increases in firm value (Roll et al., 2009) and promoting a lower-cost debt structure reflecting a combination of public and private debt that serves to increase firm value (Cao et al., 2020b).

[3] Options trading may also decrease incentives for acquiring information given that both options and private information are valuable for the reduction of risk (Huang, 2014) and no clear indication from the theoretical literature on whether options motivate more information acquisition (Cao et al., 2020b).

According to Roll et al. (2009), if prices reveal more information this can lead to more efficient allocation of corporate resources (Khanna et al., 1994; Subrahmanyam and Titman, 1999). At the same time, more informed trading induced by options markets can make stock prices more informative, leading to decreases in the risk of investing in the underlying asset (Cao, 1999; Roll et al., 2009). When more informative stock prices incorporate and reveal information about the profitability of future investment opportunities, managers can learn from more informative stock prices supporting more efficient corporate investment decision-making (Chen et al., 2007; Bond et al., 2012; Hsu et al., 2019).

Importantly, the informational benefit of options trading should depend positively on the trading volume. According to Blanco and Wehrheim (2017), 'liquidity should attract liquidity' (Pagano, 1989). Informed agents will be more willing to trade on private information in markets with higher trading volumes given that these markets provide traders with the opportunity to camouflage their trades (Kyle, 1985; Glosten and Milgrom, 1985). Conversely, informed traders abstain from trading in low liquidity markets. Thus, the information benefits from options trading depend on whether the market for options has sufficient volume so as to make informed traders more active (Admati and Pfleiderer, 1988; Chowdhry and Nanda, 1991; Pagano, 1989; Blanco and Wehrheim, 2017). Therefore, the informational benefits of options trading should be directly associated with the intensity or volume of traded options, reflecting the degree of activity of market participants in relevant markets.

According to Ferracuti and Stubben (2019), uncertainty about firms' fundamentals stems both from underlying economic factors and from information uncertainty. The first cannot be resolved via information gathering while the second can be reduced through the accumulation of information. In case uncertainty arises as a result of incomplete information, the existence of any factor that mitigates uncertainty about investment outcomes such as the activity in the options market should promote more efficient managerial decision-making by reducing negative consequences of uncertainty (Lambert et al., 2007; Ferracuti and Stubben, 2019). In this context, we expect that as stock prices become more informative and more efficient price discovery reduces information asymmetries between firm insiders and outside investors with higher options trading volumes, adverse selection and moral hazard problems that amplify investment inefficiency would be mitigated. We thus anticipate that higher options trading activity, manifested through higher trading volumes, should help reduce investment inefficiencies as it improves the overall informational efficiency of firms. As options trading activity also facilitates monitoring exerted by firm outsiders, it should further mitigate managerial opportunistic exploitation of superior information that these agents possess, providing them with incentives to raise capital when the firm is overvalued. In this case, adverse selection concerns should also be mitigated, with a protective effect from investment inefficiency from both directions. At the same time, increased informational efficiency should improve the ability of capital providers to formulate more accurate expectations about firm value, facilitating external monitoring and reducing agency conflicts between firm management and firm outsiders. Resolution of such concerns should help reduce over-investment tendencies attributed to insufficient and ineffective monitoring as well as under-investment incentives related to unwillingness of capital providers to supply capital at low costs due to moral hazard concerns.

The above leads to our first research hypothesis:

H1: More active options trading manifested through higher trading volumes is positively associated with the efficiency of firm-level investment and lower deviation from optimal investment levels.

Further, higher options trading volume should help alleviate information asymmetry and moral hazard concerns for external providers of capital when the latter are main drivers of under-investment. Over-investment, on the other hand, is not so much driven by the reluctance of external capital providers to supply funding at reasonable cost; it occurs mainly when managers make excess capital investment in the presence of information asymmetries or do so to gratify their private objectives in the presence of abundant resources. Thus, the hypothesized positive association of options trading volume with investment efficiency should be stronger when it is most sensitive to addressing the concerns of capital providers for supplying funding, and less so when managerial entrenchment motives give rise to over-investment. This leads to sub-hypothesis *H1a*:

H1a: More active options trading is more strongly (negatively) associated with under-investment, compared to over-investment.

Moreover, the posited effects should be more pronounced for more uncertain and intangible or growth-option type investments. This is because of the limited degree of certainty with which the anticipated profitability from such investments can be reliably forecasted. Their anticipated outcomes can vary significantly, given that most growth options are staged and provide opportunities for contraction, exit, or abandonment (Trigeorgis and Lambertides, 2014). The posited effects should therefore manifest differently in the two components of total investment, i.e., Capex and NonCapex investments. NonCapex investments consisting of R&D and acquisition-related outlays are more related to the exercise of growth options, whereas tangible Capex investments merely expand firm assets-in-place. NonCapex investments are more inherently uncertain in nature, referring to the difficulty in predicting their possible future outcomes, compared to the more concrete and tangible Capex investments. Information asymmetry between managers and capital providers should be larger for the type of investment that is more uncertain in terms of potential success, with associated repercussions for efficient investment in the presence of such asymmetries. Capital providers are also more prone to constrain the supply of capital for investments they consider particularly uncertain with less predictable outcomes, thus triggering under-investment for more uncertain, growth-option type investments.

We thus expect that options trading volume should be more important for mitigating investment inefficiency for investments that are less tangible and more uncertain, namely for NonCapex as opposed to Capex investments. We anticipate that any benefits arising from improvement in firms' information environment from options trading volumes–with positive repercussions for efficient investment–should be stronger for investment in the form of NonCapex, compared to Capex. This leads to:

H2: More active options trading is more strongly associated with the efficiency of firm-level investment when the latter takes the form of NonCapex rather than Capex investment.

We further consider how the strength and efficiency of external monitoring moderates the association between options trading and firm investment efficiency. On one hand, more active options trading may better enable investors to uncover private information by managers, as there may be repercussions in terms of reputation loss and managerial career concerns in hiding information from investors (Cao et al., 2020a). For example, the presence of over-investment may reflect investment inefficiencies associated with poorly monitored entrenched managers (Chen et al., 2015; Choi et al., 2020). Thus, an improved information environment due to active options trading could enhance the efficiency of governance mechanisms already in place that involve better monitoring, mitigate managerial entrenchment and induce managerial behaviors that support the interests of investors. This could make the anticipated reduction in investment inefficiency due to options trading activity more pronounced for firms with a stronger information environment attributable to more effective external monitoring.

However, if the strength and effectiveness of external monitoring helps reduce investment inefficiencies by enhancing firms' information environment, the negative association between option volumes and investment inefficiency may actually be *less* strong when the quality of such monitoring is better. This is because stronger external monitoring should provide managerial discipline and thus could work as a substitutive mechanism for information advantages offered by more options trading activity. Thus, the expected reduction in investment inefficiency from options trading should be less pronounced for firms with a more effective information environment.

In effect, the existence of alternative mechanisms enhancing firms' information environment should make the anticipated mitigating effect of options volumes on efficient investment less strong. There are two reasons for this. First, effective external monitoring represents an important mechanism exerting a positive impact on firms' informational efficiency. Second, more efficient investment is supported by enhanced firm informational efficiency and therefore any mechanism that supports this enhanced efficiency should reduce the impact of active options trading on mitigate investment inefficiency, as it would work as a substitutive mechanism. This leads to our third hypothesis:

H3: More active options trading is less strongly associated with the efficiency of firm-level investment when substitutive mechanisms of external monitoring are stronger.

3. Sample Selection and Methodology

3.1 Sample selection

Our initial sample consists of all Compustat firms matched to IvyDB Optionmetrics US during the period 1996-2019. There are 274,593 unique firm-year observations in our sample during these years, of which 69,503 have data available on options volumes from Optionmetrics. Financial firms are included in our sample, in accordance with previous studies on the value-relevance of options markets trading information (e.g., Du, 2019; Chen et al., 2020). We apply the Fama and French (1997) 48 industry breakdown (hereafter FF48) to classify firms into industries. The measurement of investment efficiency in our baseline specification is made at the level of the population and before any matching of data from Compustat to Optionmetrics. The number of firms and that of usable firm-year observations are subsequently reduced due to data availability constraints. We obtain a maximum of 34,090 firm-year observations for our baseline model (see next sub-section) during our sample period; this corresponds to 4,860 unique sample firms that are included in our baseline model.

We rely on the Center for Research in Security Prices (CRSP) for returns data, Institutional Shareholder Services (ISS) for corporate governance data, Thomson Reuters for institutional holdings, and I/B/E/S for analyst data. All continuous variables are winsorized annually at 1 and 99 percentiles at the Compustat population level.

3.2 Research methodology - baseline model specification

We measure investment inefficiency as deviations from predicted levels of investment reflected in the error terms of a normative model that predicts optimal levels of investment based on growth opportunities. In our baseline specification the optimal (normal) level of investment is based on sales growth, following Biddle et al. (2009) (see also Chen et al., 2011; Benlemlih and Bitar, 2018; Gao and Sidhu, 2018):

$$INV_{i,t} = \alpha_0 + \alpha_1 Sales\ Growth_{i,t-1} + \varepsilon_{i,t} \tag{1}$$

Deviations from the predicted optimal (normal) levels of investment represent investment inefficiency (denoted *INV_INEFF*), which can take the form of over(under)-investment for positive (negative) residuals as per the model of equation (1). These deviations are captured via the error terms of regressions like equation (1) estimated each year (at the level of the population) cross-sectionally using ordinary least squares for each Fama and French (FF48) industry separately (with a requirement of at least 20 observations in an industry-year). Investment (*INV*) is defined as the sum of research and development expenditure (R&D), capital expenditure (Capex), and acquisition expenditure, less cash receipts from sale of property, plant, and equipment (PPE), multiplied by 100, scaled by lagged total assets as in Biddle et al. (2009). Following Biddle et al. (2009), the investment *INV* variable is decomposed into capital expenditure (Capex) and non-capital expenditure (NonCapex), the latter consisting of research and development and acquisition expenditures, both multiplied by 100, and scaled by lagged total assets. We also measure Capex (respectively NonCapex) investment inefficiency, denoted *Capex_INEFF* (respectively *NonCapex_INEFF*), by using the firm-specific residuals from the above regression model when the dependent variable investment takes only the form of Capex (respectively NonCapex). Details on the estimation equations for the measurement of *INV_INEFF*, *Capex_INEFF*, *NonCapex_INEFF*), and variable definitions are in the Appendix.

The different approaches used in the literature to measure investment efficiency (e.g., based on investment-cash flow sensitivity or deviations from expected levels of investment) often come with method-specific advantages but also with criticism regarding the theory underpinning them or their empirical operationalization (Gao and Yu, 2018). Roychowdhury et al. (2019) note that investment efficiency is not actually observable with researchers often using imperfect proxies, each with their own limitations. They note the economics and finance literature which discusses the various challenges that arise due to measurement error in using imperfect proxies for growth opportunities, the conflicting evidence regarding the validity of proxies for financing constraints, and misspecification issues in empirical investment models based on q theory.

We measure investment efficiency based on estimating deviations from expected levels of investment founded on accelerator theory. This theory assumes that the level of capital is proportional to the level of output and models net investment as a function of past output growth (Gao and Yu, 2010). Such models often have low explanatory power because output growth relates weakly to optimal investment, while other factors related to future growth opportunities are not taken into consideration.

In this context, recognizing that the "true" financial performance of a firm is integrally linked to its investment opportunities (Roychowdhury et al., 2019) both at present and in the future, we extend the baseline model of equation (1) by considering two additional specifications aimed at better capturing firms' future growth opportunities. Our approach in this extension is based on the measurement of growth opportunities proposed by Trigeorgis and Lambertides (2014).

We thus develop two alternative investment inefficiency measures, estimated via extensions of the model in Biddle et al. (2009), by augmenting this baseline model with more explanatory variables that better capture future growth opportunities. The first alternative measure uses firm-specific residuals from an investment model predicting the level of investment based on sales growth and a number of other variables affecting growth opportunities. These are (i) market leverage (*Lev*), or long-term debt divided by the sum of long-term debt and the market value of equity, (ii) cash flow coverage (*CFC*), or a variable that captures the firm's ability to generate excess cash, beyond covering its interest expense and debt repayment obligations, and (iii) an R&D binary variable, indicating whether a firm reports R&D expenses or not (Appendix A reports detailed variable definitions), as follows:

$$INV_{i,t} = \beta_0 + \beta_1 Sales\ Growth_{i,t-1} + \beta_2 Lev_{i,t-1} + \beta_3 CFC_{i,t-1} + \beta_4 R\&DDummy_{i,t-1} + e_{i,t} \quad (2)$$

Our second extension of the model in Biddle et al. (2009) adds an empirical proxy for the value of growth opportunities implied from the market, *GO*, as used in Cao et al. (2008) and Trigeorgis and Lambertides (2014). Deviations from the predicted level of investment, as reflected in the error terms of the model ($INV\_INEFF^{GO,M}$) signify investment inefficiency:

$$INV_{i,t} = \gamma_0 + \gamma_1 Sales\ Growth_{i,t-1} + \gamma_2 GO_{i,t-1} + u_{i,t} \quad (3)$$

$GO_{i,t-1}$ captures the percentage of a firm's market value arising from future growth opportunities, estimated by subtracting from the current market value of the firm the perpetual discounted stream of firm operating cash flows under a no-growth policy. Detailed definitions for all variables are provided in Appendix A.

To estimate the association of options trading volume in year *t* with investment efficiency in year *t+1*, we estimate the following baseline model based on equation (1) for the full sample period:

$$INV\_INEFF_{i,t+1}\ (or\ Capex\_INEFF_{i,t+1}, or\ NonCapex\_INEFF_{i,t+1}) = \delta_0 + \delta_1 LnOptVol_{i,t} + \sum_p \xi_p Controls_{p,i,t} + \sum_m \varphi_m Year\ Fixed\ Effects_m + v_{i,t} \quad (4)$$

where $v_{i,t}$ is the error term. The dependent variable can take the form of total signed investment inefficiency $INV\_INEFF_{i,t+1}$ or signed investment inefficiency in terms of Capex and NonCapex separately. In the extensions based on equations (2) and (3), alternative measures $INV\_INEFF^{GO}_{i,t+1}$ and $INV\_INEFF^{GO,M}_{i,t+1}$ (and their subcomponents) are obtained, respectively, in separate estimations of the above equation (4).[4] The independent variable of interest in equation (4) is $LnOptVol_{i,t}$, which is the natural logarithm of one plus the total annual dollar options volume (in $000) in a fiscal year. We calculate total annual dollar options volume based on Roll et al. (2009): for each stock, we multiply the daily trading volume with the midpoint of the end-of-day bid-ask spread for each options contract on the stock, and then aggregate all listed options contracts on the particular stock across all trading days during a fiscal year. The coefficient for $LnOptVol_{i,t}$ should be negative (positive) and significant in the case that the volume of options trading attenuates (accentuates) investment inefficiency.

[4] We also estimate for these two alternative measures the Capex (and NonCapex) investment inefficiency, denoted $Capex\_INEFF^{GO}$ and $Capex\_INEFF^{GO,M}$ (respectively $NonCapex\_INEFF^{GO}$ and $NonCapex\_INEFF^{GO,M}$) by using the firm-specific residuals from the regression model of equations (2) and (3), respectively, when investment takes the form of Capex (NonCapex).

The control variables are based on the determinants of investment employed by past research (e.g., Biddle et al., 2009; García Lara et al., 2016; Benlemlih and Bitar, 2018). These include financial leverage ($Lev_{i,t}$); firm size ($LogTA_{i,t}$); the market-to-book ratio ($MB_{i,t}$); a negative profit indicator ($Loss_{i,t}$); firm age ($LogAge_{i,t}$); cash flow from operations to sales ($CFOSales_{i,t}$); tangibility based on net PPE over assets ($Tangibility_{i,t}$); the length of the operating cycle ($OperCycle_{i,t}$); an indicator variable of whether a firm distributes dividends or not ($Dividend_{i,t}$); an indicator for financial slack based on the intensity of cash over net PPE ($Slack_{i,t}$); and a proxy for bankruptcy risk based on Altman (1968) ($ZScore_{i,t}$). We also include controls for the standard deviations of cash flow from operations ($\sigma(CFO)_{i,t}$), sales ($\sigma(Sales)_{i,t}$) and investment ($\sigma(I)_{i,t}$). Equation (4) is estimated with year fixed effects and standard errors double-clustered at the firm and the industry level (FF48 sectors). Detailed variable definitions are provided in the Appendix.

3.3 Research methodology - alternative model specification

Measuring investment inefficiency does not come without challenges as it is inherently not observable (Roychowdhury et al., 2019). These challenges relate to measurement errors when using proxies to capture growth opportunities, the effect of financing constraints and misspecification in empirical investment models. Biddle et al. (2009)-type models are criticized for the assumption that firms can adjust their capital fully within one period, whereas capital investment typically requires substantial planning, installation and delivery time (Gao and Yu, 2018). For this reason, we use more than one specification for measuring investment (in)efficiency for robustness purposes.

In addition, we estimate investment inefficiency using firm-specific levels of cash and leverage as ex ante firm-specific characteristics may affect the likelihood of a firm to over- or under-invest, based on Biddle et al. (2009), Cheng et al. (2013) and Chen et al. (2017b). We calculate the ranked variable $OverFirm_{i,t}$, which represents the average of ranked decile measures of cash and leverage, calculated according to year and Fama-French FF48 industry sectors (Chen et al., 2017b), and rescaled from 0 to 1. The underlying premise of Biddle et al. (2009) is that firms without cash are more likely to be financially constrained and thus prone to under-invest, while firms with high cash balances are more vulnerable to agency problems (Jensen, 1986) and more prone to over-invest. Furthermore, firms with high leverage should also be more prone to under-investing in case they are more financially constrained and thus more vulnerable to debt overhang problems (Biddle et al. 2009). Under this premise, a firm's likelihood to over(under)-invest increases (decreases) with cash and decreases (increases) with leverage. For the $OverFirm_{i,t}$ measurement, leverage is multiplied by minus one so that it increases with the likelihood of over-investment, while a high (low) value of $OverFirm_{i,t}$ is indicative of a firm prone to over(under)-investment.

In this alternative model specification, to estimate the association of options trading volume in year *t* with investment efficiency in year $t+1$, we follow the methodology of Chen et al. (2017b) based on Biddle et al. (2009) (subsequently employed in other research e.g., Cheng et al, 2013 and García Lara et al., 2016) and estimate the following equation:

$$Inv_{i,t+1}\ (or\ Capex_{i,t+1}, or\ NonCapex_{i,t+1}) = \zeta_0 + \zeta_1 LnOptVol_{i,t} + \zeta_2 OverFirm_{i,t} + \zeta_3 LnOptVol_{i,t} \times OverFirm_{i,t} + \sum_n \theta_n Controls_{n,i,t} + \sum_m \psi_m Year\ Fixed\ Effects_m + e_{i,t} \quad (5)$$

Our independent variables of interest are $LnOptVol_{i,t}$ and the multiplicative term with $OverFirm_{i,t}$. If options trading volume is negatively associated with under-investment, then coefficient ζ_1 should be positive and significant. Following Biddle et al. (2009), the coefficient ζ_1 measures the relation between options trading volume and investment when under-investment is most likely. As the coefficient ζ_3 measures the incremental relation between options trading volume and investment as over-investment becomes more likely, the sum of the coefficients $\zeta_1 + \zeta_3$ measures the relation between options trading activity and investment when over-investment is most likely (Biddle et al., 2009). If options trading volume is negatively associated with over-investment, $\zeta_1 + \zeta_3$ should be negative.

Control variables used in equation (5) include proxies for monitoring and governance mechanisms and standard determinants of investment (Biddle et al. 2009; Cheng et al., 2013; García Lara et al., 2016; Chen et al., 2017b). Controls for monitoring/governance include institutional holdings ($INST_{i,t}$) and coverage by financial analysts ($LogAnalysts_{i,t}$). We also include a proxy for accounting quality ($AQ_{i,t}$) as in Chen et al. (2017b). These variables are also interacted with $OverFirm_{i,t}$ to control for their association with over- and under-investment. Controls for investment drivers include leverage at the industry level ($Ind\ K - structure_{i,t}$) and other standard controls used previously.[5] Equation (5) is estimated with year fixed effects and standard errors double-clustered at the firm and industry levels (FF48 sectors). Variable definitions are provided in the Appendix.

4. Empirical findings

4.1 Descriptive Statistics

Table 1 reports descriptive statistics for all sample firm-year observations used in our baseline model equation (4) during 1996-2019, for variables related to measuring investment (in)efficiency, option

[5] Specifically, the control variables included are: firm size ($LogTA_{i,t}$), the market-to-book ratio ($MB_{i,t}$), cash flow from operations ($CFOSales_{i,t}$), a tangibility indicator ($Tangibility_{i,t}$), a binary dividend payment indicator ($Dividend_{i,t}$), the firm's operating cycle ($OperCycle_{i,t}$), a negative profit indicator ($Loss_{i,t}$), Altman's (1968) Z score for bankruptcy risk ($ZScore_{i,t}$), firm age ($LogAge_{i,t}$), and the standard deviations of cash flow from operations ($\sigma(CFO)_{i,t}$), sales ($\sigma(Sales)_{i,t}$) and investment ($\sigma(I)_{i,t}$).We do not include leverage as a separate regressor, as this variable was used for the calculation of $OverFirm_{i,t}$ (Biddle et al., 2009; Chen et al., 2017b).

volumes, and main variables used as controls or employed in supplementary analyses and tests for endogeneity. All variables reported in Table 1 are defined in the Appendix. The average (median) investment (as % of total assets) for the sample is 13.846% (8.918%) and relevant values fall to 5.722 (3.635) for Capex and 8.379% (2.135%) for NonCapex investment. Average and median values for abnormal (inefficient) investment, total or decomposed into its Capex and NonCapex components, are negative, indicating a tendency towards under-investment for the sample of options listed firms. Values for the alternative measures of investment inefficiency we use based on the extended models of equations (2) and (3) , $INV\_INEFF_{i,t}^{GO}$ and $INV\_INEFF_{i,t}^{GO,M}$, are generally very close to the ones observed for baseline *INV_INEFF* for total investment and also Capex and NonCapex separately. $OverFirm_{i,t}$ has an average (median) value of 0.509 (0.50). The average (natural logarithm of one plus) options dollar volume $LnOptVol_{i,t}$ has a mean (median) value of 0.360 (0.064), exhibiting important difference between the mean and median confirming that options trading volume is highly skewed, as observed in Cao et al. (2020b). This difference is also observed in dollar volumes obtained from call and put options separately, but not for non-dollar or delta-adjusted option volumes. The average age of our sample firms is 22 years, and they appear to mainly rely on equity rather than debt financing (the average leverage ratio is lower than 20%). On average, 25% of firm-year observations report losses and 51% distribute dividends. About 40% have a credit rating for their long-term debt, while roughly 16% are also traded in CDS markets. Regarding other control variables, the average (median) Z-Score is 1.029 (1.070), while on average net PP&E is 27.6% of total assets, as seen by the tangibility indicator. The summary statistics for the rest of the variables are generally consistent with prior studies (e.g. Chen et al., 2017b; Choi et al., 2020).

Insert Table 1 about here.

4.2 Main empirical findings

Table 2 reports OLS results of our baseline equation (4) for the entire sample, for the over-investment and under-investment subsamples separately. The latter are defined as $INV\_INEFF_{i,t+1} \geq 0$ ($INV\_INEFF_{i,t+1} < 0$), respectively. The Table also reports results when the dependent variable takes the form of $Capex\_INEFF_{i,t}$ ($NonCapex\_INEFF_{i,t}$), reflecting Capex and NonCapex investment inefficiency. Panels A, B, and C of Table 2 report relevant results when estimating investment inefficiency based on equations (1), (2) and (3), as $INV\_INEFF_{i,t+1}$, $INV\_INEFF_{i,t+1}^{GO}$ and $INV\_INEFF_{i,t+1}^{GO,M}$, respectively. Results from the baseline model of Panel A show that $LnOptVol_{i,t}$ is negatively and significantly (at the 1% level) associated with investment inefficiency, confirming *H1*. This result is confirmed for the under-investment but not for the over-investment sample. For the under-investment sample, the coefficient of -0.9402 is larger, in absolute terms, compared to the relevant coefficient for the full over-and under-investment sample (a value of -0.9161). Turning to the two components of investment, $LnOptVol_{i,t}$ is a negatively significant determinant of NonCapex but not of Capex investment inefficiency. Thus, our findings indicate that the dollar volume of options trading is strongly and significantly associated with investment inefficiency; this result is mainly driven by under-investment and inefficient investment in NonCapex rather than Capex. Evidence from Panels B and C when measuring investment inefficiency based on extended models of equations (2) and (3). $INV\_INEFF^{GO}_{i,t+1}$ and $INV\_INEFF^{GO}_{i,t+1}$, respectively, are in analogous direction, in terms of sign and significance, to the ones from Panel A.[6]

These results are consistent with higher options trading volume more strongly mitigating under-investment rather than over-investment, as predicted by *H1a*. In addition, we find that options volume is negatively associated with investment inefficiency when the outcome of firm investment is inherently more uncertain, that is for NonCapex, rather than Capex investments, confirming *H2*. This is consistent with higher option trading volumes being positively linked to the information environment of firms when most needed, as is the case when the nature of investment is less certain.

Insert Table 2 about here.

Regarding the coefficient estimates of the other independent variables, it appears that market-to-book is a significant triggering factor for investment inefficiency, with the exception of under-investment. Firms with high market-to-book ratios tend to be associated with higher levels of investment growth and over- (but not under)-investment, consistent with Benlemlih and Bitar (2018). Firm size, $LogTA_{i,t}$, appears to protect from investment inefficiency as more established firms have learned through experience how to invest more efficiently through time. This result reverses in the case of under-investment, consistent with past research with similar research design and comparable sample (Benlemlih and Bitar, 2018). The same result appears to hold for firm age. Leverage negatively and significantly relates to investment inefficiency, as high levels of debt limit firms' ability to raise additional external financing (likely to be invested non-efficiently). This also seems the case for firms incurring losses and to some extent for firms with less financial slack. The latter appears to have a disciplining effect and is negatively associated with investment inefficiency.

Tangibility has positive and significant coefficients for the full, the under-investment and the Capex only samples, but not for the over-investment sample. This indicates that a high level of tangible assets is associated with inefficient investment, particularly over-investment and investment in Capex, but not with under-investment. This is consistent with managerial hybris motives and growing the firm beyond its optimal size through excessive investments in tangible assets. The volatilities of investment, cash flows and sales are generally positively and significantly associated with investment inefficiency in the form of over-, but not under-investment, and for NonCapex investment in

[6] The results of Table 2, Panel B, remain unchanged if the leverage variable, $Lev_{i,t}$ is excluded as an independent variable in equation 4 (as $Lev_{i,t}$ also appears on the right-hand side of equation 2 that estimates $INV\_INEFF^{GO}_{i,t+1}$).

particular. Higher volatility in these fundamentals is associated with intangible-type investments that are inherently more uncertain, as is the case of NonCapex. The length of the operating cycle and the risk of bankruptcy (proxied by Altman's Z-Score) are factors mitigating total investment inefficiency and over-investment, while being significantly associated with under-investment. The length of the operting cycle indicates a firm needs more time to collect cash and a limited ability to undertake long-term investment when this cycle is long. The risk of bankruptcy tightens financial constraints faced by the firm producing a similar effect on inefficient investment. Finally, the availability of cash proxied by cash flow generation ability, $CFOSales_{i,t}$, allows firms more opportunities to inefficiently invest in tangible-type investments.

Table 3 reports OLS results for the alternative model specification of equation (5). The coefficient for $LnOptVol_{i,t}$ is significantly positive at the 1% significance level with a value of 1.8798 (respectively 2.1217) when the dependent variable is next year's total (respectively NonCapex) investment. It is not statistically significant when the dependent variable is Capex investment. Thus, for firms that are most likely to under-invest (*OverFirm* = 0), a higher options trading volume is associated with higher future total and NonCapex (but not Capex-type) investment. But the coefficient for the interaction term $LnOptVol_{i,t} \times OverFirm_{i,t}$ is negatively significant at the 1% level, with a value of -3.3961 (respectively -4.0242) for the total (respectively NonCapex) investment specifications. It is again non-significant in the Capex model estimation. The overall effect of options trading volume on investment among firms that are more prone to over-invest is given by the sum of the coefficient estimates of $LnOptVol_{i,t}$ and $LnOptVol_{i,t} \times OverFirm_{i,t}$, which should be significantly negative when the volume of options trading protects from over-investment, as the latter becomes more likely The *p-value* for the Wald test that the sum of the coefficients of $LnOptVol_{i,t}$ and $LnOptVol_{i,t} \times OverFirm_{i,t}$ is virtually zero, strongly rejecting (at the 1% level) the null hypothesis in the case of the total and NonCapex model specifications; this essentially indicates that options trading volume is negatively associated with over-investment. Thus, findings from Table 3 confirm previous evidence from Table 2 suggesting that options trading volumes are negatively associated with inefficient investing. These findings are mainly driven by NonCapex type investment such as R&D and acquisitions involving growth options, rather than Capex investment expanding tangible assets-in-place. However, in contrast to findings from Table 2, evidence from Table 3 under this alternative model specification indicates that options trading activity is negatively associated with investment inefficiency from either direction, and not only for under-investment as suggested in Table 2.

Insert Table 3 about here.

Regarding the rest of the variables, $OverFirm_{i,t}$ is generally positively associated with investment, and the same applies for analyst following $LogAnalysts_{i,t}$. Institutional ownership and accounting quality do not seem related to the levels of future investment. Capital structure at the industry level, firm size and the loss and dividend payment indicators, are all negatively associated with levels of investment, in line with smaller, leveraged, loss-making and dividend-paying firms investing less as shown in past research (e.g., Chen et al., 2017b). The opposite is generally observed for firms with high market-to-book ratios and asset tangibility, showing that higher growth and tangible assets in place are associated with higher levels of Capex investment. For NonCapex investments, higher asset tangibility is negatively associated with this type of intangible investment. Financial slack, expressed as cash per dollar of net tangible assets, seems negatively associated with investment levels though it was found insignificant in past research (Biddle et al., 2009).

Firms' cash flow generation ability, ($CFOSales_{i,t}$), the length of the operating cycle, and the bankruptcy risk proxy are negatively associated with total and NonCapex investment, and positively associated with Capex investment. Similarity in coefficient signs and significance levels observed between the total and NonCapex equations, but not for Capex investment, is in line with the more tangible nature of Capex and the fact that the association of options volume with investment efficiency is mainly driven by NonCapex investment involving more growth options than assets-in-place. The volatilities of investment and cash flow positively and significantly relate to future investment.

4.3 Controlling for endogeneity

Our above baseline results are consistent with our main hypothesis that options trading volume activity is positively associated with firm-level investment efficiency. However, potential endogeneity concerns could muddy this association. This could be the case if both options trading volume and firm-level investment efficiency are jointly affected by factors unobservable to the empiricist but observable to traders (Blanco and Wehrheim, 2017), as may be the case, for example, if traders adjust their trading patterns in light of anticipated efficient investing by firms. If such factors correlate positively with the level of options trading, model inferences could be biased. In a similar vein, options volume could be endogenously determined by the efficiency of firm investment or efficient investment and options trading volumes may be simultaneously determined by the informational efficiency of firms. Following previous research, we use two main methods to mitigate such potential endogeneity concerns.

First, following Roll et al. (2009) and other scholars applying their methods (e.g., Blanco and Werheim, 2017; Cao et al., 2020a; Cao et al., 2020b, Chen et al., 2020), we employ a two-stage generalized method of moments (GMM) estimation with instrumental variables. We use option moneyness and option open interest as instrumental variables (IVs) for options trading volume, in the belief that these variables should be essentially exogenous to both options trading volume and firm-level investment efficiency. The premise guiding the choice of these two variables as instruments for the volume of options trading is that they satisfy a relevance condition as they should be correlated with options trading volume while they also satisfy the exclusion criterion of being uncorrelated with firm-level investment efficiency. Moneyness is related to options trading because of a preference of informed (uninformed) traders for out-of-the-money (in-the-money) options, and because volatility traders tend to avoid deep in- and out-of-the-money options (Roll et al., 2009; Blanco and Wehrheim, 2017) in preference for at-the-money options (Chakravarty et al., 2004).[7] At the same time, open interest indicates unsettled option contracts (Chen et al., 2020) and should be higher when more open positions for option calls and puts exist and when options volumes are higher (Ali et al., 2020). Open interest should be associated to trading volumes in the same way as the number of shares outstanding and stock trading volume (Cao et al., 2020a). This is in line with evidence by Amin and Lee (1997) confirming a significant association between levels of open interest and informed trading, by observing increases in open interest for call (put) options in anticipation of positive (negative) earnings announcements. Option moneyness is defined as the annual average absolute difference between a firm's stock price and the strike price of traded options as in Chen et al. (2020) and Ni et al. (2005), while open interest is measured as the average open interest across all options on a firm's stock throughout the fiscal year as in Cao et al. (2020b).

As option exchanges periodically list new options with strike prices close to the stock's market price (Blanco and Wehrheim, 2017), there is no reason to expect that the degree of moneyness of traded options should be linked intrinsically to investment efficiency. The same holds about open interest and efficient investment. Open interest (with both call and put options) will be higher when there are more open positions for calls and puts, and this should not be intrinsically linked to efficient investing.[8]

Table 4 reports the second-stage results of re-estimating equation (4) using a two-stage GMM instrumental variable approach, with $Moneyness_{i,t}$ and $OpenInterest_{i,t}$ as the excluded IVs for identification.[9] Panels A, B, and C of Table 4 report relevant results when defining investment inefficiency as $INV\_INEFF_{i,t+1}$, $INV\_INEFF^{GO}_{i,t+1}$ and $INV\_INEFF^{GO,M}_{i,t+1}$ respectively.

Insert Table 4 about here.

Table 4, Panels A, B and C, confirms that the coefficient signs and the statistical significance of our independent variable of interest, $LnOptVol_{i,t}$, remain unchanged in the two-stage GMM estimation,

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[7] For a more detailed explanation why option moneyness should be related to options trading, see Blanco and Wehrheim (2017), p. 111.

[8] One might counter argue that moneyness may not represent an optimal IV, as it depends on stock price movements and exchanges introduce more options for stocks which are more volatile (Cao et al., 2020a). In this case, moneyness may not represent a proper IV if it is driven by stock market characteristics which also associate with efficient investment. Open interests is used as an additional IV to address such concerns. In any case, tests on the validity of the selected IVs can be performed in parallel to the GMM estimation, as we demonstrate in our estimation results.

[9] The first-stage estimation results, omitted for brevity, are made available from the authors upon request.

in comparison to our baseline model of equation (4) reported in Table 2.[10] Options trading volume appears to negatively and significantly associate with firm-level investment inefficiency, mainly driven by NonCapex investment. This primarily holds in the case of investment inefficiency taking the form of under- but not over-investment. The GMM coefficients reported in all Panels of Table 4 are also consistently larger in absolute terms (i.e., more negative) compared to the OLS results of Table 2. This is in line with as Blanco and Wehrheim (2017) and Cao et al. (2020a) in the context of their own research questions. The smaller size of OLS coefficient estimates compared to GMM estimates is potentially related to options volume trading measured with some error due to omitted variables simultaneously affecting firms' efficient investment and making underlying firms more attractive to informed traders (Blanco and Wehrheim, 2017), such as in case a firm's pre-existing informational environment acts as such a factor.

Table 4 also reports *Hansen's J statistic*, a heteroskedasticity-consistent test of overidentification restrictions in GMM estimation under the joint null hypothesis that the instruments are valid and the excluded instruments are correctly excluded from the estimated equation. In all but the Capex model specification, the *Hansen J statistic* indicates failure to reject the null hypothesis that the instruments employed are valid. Thus, our baseline results also hold under the two-stage GMM IV estimation with moneyness and open interest used as instruments for the intensity of options volumes trading.

Second, we apply propensity score matching (PSM) among firms with high vs. low options trading activity to test whether otherwise similar matched firms that differ only in the volumes of their traded option contracts exhibit distinctly different levels of firm-level investment inefficiency. High (low) options trading activity firms are defined as those with options trading volume above (below) their industry (based on FF48 sectors)-year median. The former ("high") group represents our treatment firms, while firms with "low" options trading activity represent the control firms. We perform PSM between our treatment and control firms based on one to one, nearest-neighbor matching with replacement where all the control variables used in equation (4) are employed to produce the propensity scores, following Ali et al. (2020). Table 5 Panel A reports average treatment effects obtained from PSM. Panel B reports the results of the PSM estimation of equation (4) for treatment and control firms, estimated for the entire sample, for the over-investment (under-investment) subsamples separately. Investment inefficiency is estimated both in terms of Capex and NonCapex. For brevity, detailed estimation results for control variables are omitted from the Table.[11]

[10] The results of Table 4, Panel B, remain unchanged if the leverage variable, $Lev_{i,t}$ is excluded as an independent variable in equation (4) (as $Lev_{i,t}$ also appears on the right-hand side of equation (2) that estimates $INV\_INEFF_{i,t+1}^{GO}$).

[11] For brevity, from Table 5 onwards, we only report results for one of our investment inefficiency measures, baseline INV_INEFF based on equation (1) and not for the alternative measures based on equations (2) and (3), INV_INEFF^{GO} and $INV\_INEFF^{GO,M}$. For these alternative measures, results are made available upon request from the authors.

Insert Table 5 about here.

According to Panel A of Table 5, the average treatment effects between high and low options volume firms indicate significantly lower investment inefficiency for the treatment group. This applies to investment inefficiency in terms of total, as well as for Capex and NonCapex investment. Treatment effects for all other control variables used in our baseline equation (4) indicate statistical insignificance among the two groups.

We also estimate equation (4) for firms with high options trading volumes and their PS-matched low volume counterparts. Panel B of Table 5 confirms that the full set of our main analyses reported in Table 2 remains qualitatively similar. We interpret the results reported in Tables 4 and 5 as supportive of our main finding that options trading volumes are negatively associated with investment inefficiency and are not likely driven by endogenous characteristics of firms listed in options markets or by factors that simultaneously induce high options trading activity and more efficiency in firm-level investment.

4.4 The role of external monitoring

To examine whether the volume of options trading relates to investment efficiency through an external monitoring channel, as predicted by *H3*, we estimate equation (4) again, this time interacting our independent variable of interest $LnOptVol_{i,t}$ with measures for the strength of external monitoring. Table 6 summarizes our estimation results of equation (4) when interacting $LnOptVol_{i,t}$ with a variable indicating the magnitude of institutional blockholder ownership, and when estimating this equation for firms with and without a Standard and Poor's (S&P) credit rating of their long-term debt separately. The institutional blockholder ownership indicator takes the value of one (zero) if a firm is above (below) the sample-year median for institutional blockholder ownership (>= 5%, as percentage of fiscal year-end market capitalization) using data from Thomson Reuters 13F. Larger blockholder institutional ownership should increase the strength of external monitoring on the firm, while the presence or absence of S&P credit rating provides evidence of an independent external assessment (or lack of it) of the firm's long-term survivability prospects.

Insert Table 6 about here.

We observe from Table 6 that the intensity of institutional blockholder ownership associates negatively and significantly with firm-level investment inefficiency. This indicates that stronger external monitoring associated with institutional ownership helps mitigate inefficient investment. Importantly, the coefficient of the interaction term between options trading volume and institutional blockholder intensity is positive and statistically significant, indicating that stronger external monitoring countervails the mitigating effect of options trading activity on inefficient investment, confirming the prediction of *H3*. Furthermore, when separately estimating equation (4) for firms with and without a long-term debt S&P credit rating, the finding of a positive relation between options trading volume and firm investment efficiency is concentrated in firms without an S&P credit rating or firms operating in a poorer firm information environment compared to firms with such ratings.

The above findings indicate that as the strength of monitoring and information-enriching mechanisms improve, any mitigating role of options trading for investment inefficiency becomes weaker and less necessary. In a way, the intensity of options trading activity works in the same direction as (and acts as a substitute for) the strength of external monitoring in helping alleviate firm investment inefficiency. Presumably both options trading activity and external monitoring help enrich a firm's information environment, permitting a more accurate assessment of the firm's investment opportunities.

5. Supplementary Analyses and Robustness Tests

5.1 Supplementary Analyses

In this section we report a number of supplementary analyses and robustness controls for our main results. Table 7 reports the results of estimating equation (4) separately (a) for firm-year observations with unexpected investment[12], (b) for firms with number of business and geographical segments above or below the sample-year median, and (c) for firms with and without CDS trading.

Firstly, unexpected investment is considered an indicator of poor firm performance (Chen et al., 2017b). Firms with high levels of unexpected investment could be more strongly affected by any mitigating effects of options trading activity on investment inefficiency. This is because such firms should be in great need of any factor with a positive effect on efficient investing due to their poorer-than-average performance, compared to firms with low unexpected investment. Unexpected investment is measured as the deviation of a firm's investment from expected levels through estimating a regression of total investment on growth opportunities (based on lagged Tobin's Q) and considering the firm-specific residuals from this equation (Biddle et al., 2009; Chen et al., 2017b).

Second, we estimate equation (4) for firm-year observations with higher vs. lower than median business and geographic diversity and complexity, proxied by the number of business and geographical segments in which a firm operates (Duchin et al., 2010). Competing in multiple industries and geographical segments indicates that a firm affronts more complex operational and informational environments (Bushman et al., 2004). Operating in a more vs. less complex business

[12] Chen et al. (2017b; 228) expect that firms characterized by high levels of unexpected investment, which is considered as an indicator of poor performance, should be more influenced by analyst forecast quality on investment efficiency than firms with low levels of unexpected investment. The underlying assumption behind this conjecture is that poor firm performance goes hand in hand with important deviations from expected investment levels. Therefore, high levels of unexpected investment imply that firms deviate from relevant optimal levels because of poor performance, so any factor that can mitigate investment inefficiency should be more important in doing so for this sample of firms in particular.

and geographical context would enable a firm to benefit more from information environment-enhancing effects associated with options trading activity and affecting the efficiency of the firm's investment. For more informationally-obscure firms there is likely more private information to be discovered by option market participants, so options market activity may play a more important role in information asymmetry mitigation. However, as multi-segment operations have been associated with capital allocation inefficiency and lower firm value (Anagnostopoulou et al., 2021; Stein, 1997; Lamont and Polk, 2002; Denis et al., 2002), they may moderate negatively the association between options trading activity and inefficient firm investment.

Finally, we re-estimate equation (4) separately for firms with traded options which have (or have not) traded CDSs. Recent research has shown the existence of direct interactions between different types of derivatives of the same firm (Cao et al., 2019) as end-user demand for one derivative instrument can affect the pricing of other derivatives with correlated unhedgeable risks (Gârleanu et al., 2009; Chen et al. 2019). Firms with both traded options and CDSs have improved informational efficiency, making the relation of options trading volumes and firm investment efficiency less significant.

Insert Table 7 about here.

Table 7 shows that the negative association between options trading volumes and investment inefficiency holds when unexpected investment is higher than the sample-year median, but not when it is lower. We interpret this finding as indicative of trading volumes improving the information environment for firms most in need of such improvement due to their low prior performance. Interestingly, our baseline results hold mainly for firms which operate in a low (below the sample-year median) number of operating and geographical segments. This suggests that the negative association of options trading activity with investment inefficiency holds mainly when firm complexity is low, consistent multi-segment operations associating with capital allocation inefficiency that cannot be resolved by the information enriching role of options trading volumes.. Finally, our main results are driven by firms which do not trade in the CDS market. This suggests a substitutive role of trading in multiple markets with respect to firms' informational environment. There is little evidence on options trading activity significantly explaining investment efficiency when firms trade in CDS. Overall, the above findings from supplementary analyses are in line with trading in options markets being positively related with firms' optimal investment allocation, with the association being stronger when other information environment-enhancing mechanisms are less strong. This again is more prevalent when investment is more uncertain and involves NonCapex rather than Capex.

5.2 Robustness Tests

For robustness, Table 8 reports estimation results for the baseline equation (4) when options trading activity is measured differently. More specifically, we use the total number of option contracts rather than their dollar value (Ali et al., 2020), and also employ call and put option volumes separately (Cao et al., 2020a). We also report results when using the absolute delta-weighted option volume, based on Lakonishok et al. (2007). This is because the majority of trading takes place in at-the-money options yet trading in- or out-of-the money options might convey different information. Thus, trading activity measured using all options might be an imperfect proxy about trading activity that incentivizes information gathering by investors (Cao et al., 2020a). Detailed definitions are provided in Appendix A for all variables.

Insert Table 8 about here.

The results of Table 8 confirm that alternative ways of measuring options trading activity do not produce any qualitative change in our results. The coefficient of options trading volumes, regardless of how defined, remains negative and statistically significant at 1%. The options volume is also negative and significant (at the 5% level) when using delta-weighted volume. The same applies when the number, as opposed to the dollar value, of options contracts is used as a proxy for trading activity (at 10%). Overall, our results are robust to alternative definitions for the intensity of options trading.

6. Conclusion

This paper examines the association between options trading activity and firm investment efficiency measured as deviation from optimal investment. Prior research has shown that options trading activity improves the informational efficiency of firms. Firm-level investment efficiency has also been shown to depend on firms' information environment, with adverse selection exacerbating both over- and under- investment problems (García Lara et al., 2016). Thus, we examine whether options trading volume, a factor that reduces information asymmetries and improves access to internal firm information for outsiders, is associated positively with improved firm-level investment efficiency or lower deviations from optimal levels of firm investment. We examine this research question for US firms with options trading activity during 1996-2019 and find that options trading volumes positively and significantly associate with firm-level investment efficiency. Our main findings are more prevalent in the case of under-, rather than over-investment, and are mostly driven by NonCapex rather than Capex-type investment. The evidence suggests the volume of options trading helps mitigate information asymmetry and moral hazard concerns related to under-investment. Options trading activity is more negatively associated with (and may potentially help mitigate) firm investment inefficiency when the outcome of investment is more uncertain and primarily entails NonCapex consisting of R&D and acquisitions that involve more growth options, compared to more tangible Capex investment that merely adds to a firm's assets-in-place.

Results are robust under alternative model specifications and different ways of measuring options trading activity. Our evidence is also robust to endogeneity controls. Endogeneity concerns may stem from the possibility that both options trading volumes and the degree of firm investment inefficiency may be simultaneously determined by the quality of firms' information environment. To help alleviate such endogeneity concerns, we employ a two-stage GMM estimation, using option contract moneyness and open interest as instrumental variables for the options trading volume. We additionally employ PSM between firms with high vs. matched firms with low options trading volumes. Results support our main finding of a positive association between options trading activity and firms' investment efficiency.

We highlight an external monitoring channel as a potential mechanism through which options trading volumes could associate with investment inefficiency, given that firms' information environment can be significantly shaped by the presence of strong external monitoring that limits managerial entrenchment and alleviates adverse selection and moral hazard problems driving inefficient investment. We find that when the strength of external monitoring and information-enriching mechanisms improve, proxied by the size of institutional block holdings and the existence of long-term S&P debt rating, the association between the volume of options trading and investment efficiency significantly weakens. This is indicative of options trading volumes and the strength of external monitoring working as substitutes in supporting more efficient levels of investment through alleviating information asymmetry and moral hazard concerns stemming from a poor firm information environment. Finally, we observe that the negative association between options trading activity and investment inefficiency particularly holds for firms with high unexpected investment (a signal of poor performance) and for firms with no CDS traded on their options. Overall, this evidence suggests that the positive association of options trading volumes with firm investment efficiency is stronger when firms' informational efficiency is lower.

Our evidence is consistent with active option market trading helping alleviate information asymmetry and moral hazard concerns associated with deviations from optimal levels of corporate investment. Our findings provide, for the first time, evidence on the size of firm-level investment inefficiency and its relation with option market trading activity. Overall, our findings suggest that the managerial skills and organizational capabilities associated with trading in derivatives markets also benefit firms' investment activities through enhancing the optimal allocation of corporate resources and investment efficiency.

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Appendix A. Variable Definitions

Investment efficiency-related variables (Source: Compustat)	
INV	is the sum of research and development expenditure, capital expenditure, and acquisition expenditure, less cash receipts from sale of property, plant, and equipment (PPE), multiplied by 100, and scaled by lagged total assets.
Capex	is capital expenditure, multiplied by 100, and scaled by lagged total assets.
NonCapex	is the sum of research and development expenditure and acquisition expenditure, multiplied by 100, and scaled by lagged total assets.
INV_INEFF	is an investment inefficiency measure, calculated as in Biddle et al. (2009), by using firm-specific residuals from an investment model predicting the level of investment based on growth opportunities, as measured by sales growth. Deviations from the predicted level of investment, as reflected in the error terms of the model signify investment inefficiency: $INV_{i,t} = a_0 + a_1 Sales\ Growth_{i,t-1} + \varepsilon_{i,t}$ where *INV* is as previously defined, and $Sales\ Growth_{i,t-1}$ is the change in sales from year *t - 2* to year *t – 1*. The investment model is estimated cross-sectionally for each year and FF48 industry with at least 20 observations in a year.
INV_INEFF^{GO}	is an investment inefficiency measure, calculated via an extension of the model in Biddle et al. (2009), by using firm-specific residuals from an investment model predicting the level of investment based on growth opportunities, as measured by sales growth and the following variables that Trigeorgis and Lambertides (2014) propose for affecting growth opportunities: Leverage (*Lev*), Cash flow coverage (*CFC*) and an R&D dummy variable, indicating that the firm has R&D expenses. Deviations from the predicted level of investment, as reflected in the error terms of the model signify investment inefficiency: $INV_{i,t} = \beta_0 + \beta_1 Sales\ Growth_{i,t-1} + \beta_2 Lev_{i,t-1} + \beta_3 CFC_{i,t-1} + \beta_4 R\&DDummy_{i,t-1} + e_{i,t}$ where *INV* and $Sales\ Growth_{i,t-1}$ are as previously defined, $Lev_{i,t-1}$ is defined below and $CFC_{i,t-1}$ captures the firm's ability to generate excess cash, beyond covering its interest expense and debt repayment obligations. It is calculated as. $CFC_{i,t} = \frac{Cash\ Flow\ From\ Operations_{i,t} + Cash\ and\ Cash\ Equivalents_{i,t-1}}{Interest\ Expense_{i,t} + \frac{Debt\ Repayment_{i,t} + Preferred\ Dividends_{i,t}}{1 - Tax\ Rate_{i,t}}}$ The investment model is estimated cross-sectionally for each year and FF48 industry with at least 20 observations in a year.
$INV\_INEFF^{GO,M}$	is an investment inefficiency measure, calculated via an extension of the model in Biddle et al. (2009), by using firm-specific residuals from an investment model predicting the level of investment based on growth opportunities, as measured by sales growth and the growth option variable (GO market) in Trigeorgis and Lambertides (2014). Deviations from the predicted level of investment, as reflected in the error terms of the model signify investment inefficiency: $INV_{i,t} = \gamma_0 + \gamma_1 Sales\ Growth_{i,t-1} + \gamma_2 GO(M)_{i,t-1} + u_{i,t}$ where *INV* and $Sales\ Growth_{i,t-1}$ are as previously defined and $GO(M)_{i,t-1}$ is the growth options (market) variable in Trigeorgis and Lambertides (2014), capturing the percentage of a firm's value arising from future growth opportunities (PVGO/V). It is can be inferred or estimated by subtracting from the current market value of the firm the perpetual discounted stream of firm operating cash flows under a no-growth policy $V_{i,t} = \frac{CF_{i,t}}{WACC_i} + PVGO_{i,t}$ where $V_{i,t}$ is the market value of firm *i* at time *t*, $CF_{i,t}$ is the (perpetual) operating cash flow of firm *i* at time *t* (measured as net cash flow from operating activities), and $WACC_i$ is the firm's weighted average cost of capital. See Trigeorgis and Lambertides (2014, p. 755) for details of the *GO(M)* variable calculation. The investment model is estimated cross-sectionally for each year and FF48 industry with at least 20 observations in a year.
Capex_INEFF	is a Capex investment inefficiency measure, calculated as *INV_INEFF* above, when defining investment as *Capex*. Deviations from the predicted level of investment, as reflected in the error terms of the model signify Capex investment inefficiency.
$Capex\_INEFF^{GO}$	is a Capex investment inefficiency measure, calculated as INV_INEFF^{GO} above, when defining investment as *Capex*. Deviations from the predicted level of investment, as reflected in the error terms of the model signify Capex investment inefficiency.
$Capex\_INEFF^{GO,M}$	is a Capex investment inefficiency measure, calculated as $INV\_INEFF^{GO,M}$ above, when defining investment as *Capex*. Deviations from the predicted level of investment, as reflected in the error terms of

	the model signify Capex investment inefficiency.

NonCapex_INEFF	is a NonCapex investment inefficiency measure, calculated as *INV_INEFF* above, when defining investment as *NonCapex*. Deviations from the predicted level of investment, as reflected in the error terms of the model signify NonCapex investment inefficiency.
NonCapex_INEFF^{GO}	is a NonCapex investment inefficiency measure, calculated as *INV_INEFF*^{GO} above, when defining investment as *NonCapex*. Deviations from the predicted level of investment, as reflected in the error terms of the model signify NonCapex investment inefficiency.
NonCapex_INEFF^{GO,M}	is a NonCapex investment inefficiency measure, calculated as *INV_INEFF*^{GO,M} above, when defining investment as *NonCapex*. Deviations from the predicted level of investment, as reflected in the error terms of the model signify NonCapex investment inefficiency.
OverFirm	is a ranked variable calculated as the average of a ranked decile measure of cash and leverage. Cash and leverage deciles are calculated according to year and Fama and French 48 (FF48) industries, and are rescaled from 0 to 1. Leverage is multiplied by minus one before rank calculation; so that both the cash and leverage variables increase with the likelihood of over-investment.

Options-related variable variables (Source: IvyDB Optionmetrics)	
LnOptVol	is the natural logarithm of one plus the total annual dollar options volume (in $000) in a fiscal year.
LnOptNon$Vol	is the natural logarithm of one plus the total annual number of options contracts in a fiscal year.
LnVolCalls	is the natural logarithm of one plus the total annual dollar call options volume (in $000) in a fiscal year.
LnVolPuts	is the natural logarithm of one plus the total annual dollar put options volume (in $000) in a fiscal year.
LnOptVolDelta	is the natural logarithm of the absolute delta-weighted option volume, based on Lakonishok et al. (2007) and Cao et al. (2020a).

Control variables for baseline model specification (Source: Compustat, CRSP)	
CFOSales	is the ratio of cash flow from operations to sales.
Dividend	is an indicator variable equal to 1 if the firm paid a dividend, and zero otherwise (identifying dividend payments as in Biddle *et al.*, 2009).
Lev	is an indicator for financial leverage, or long-term debt divided by the sum of long-term debt and the market value of equity (calculated by multiplying the number of shares outstanding by the stock price at fiscal year-end).
Loss	is a binary indicator taking the value of one if income before extraordinary items is negative, and zero otherwise.
MB	is the ratio of the market value of total assets (total assets plus market value at fiscal year-end, minus common shareholders' equity and deferred taxes) to the book value of total assets.
OperCycle	is a firm's operating cycle, defined as the logarithm receivables to sales plus inventory to COGS multiplied by 360.
LogTA	is the logarithm of total assets.
Slack	is an indicator of financial slack, calculated as cash divided by net property, plant and equipment.
Tangibility	is the ratio of net PPE to total assets.
ZScore	is Altman's Z score for the risk of bankruptcy (Altman, 1968), and calculated as in Biddle et al. (2009).
σ(CFO)	is the standard deviation of the cash flow from operations divided by average total assets from years *t-5* to *t-1*.
σ(Sales)	is the standard deviation of sales divided by average total assets from years *t-5* to *t-1*.
σ(I)	is the standard deviation of annual investment (*INV*) from years *t-5* to *t-1*.
LogAge	is the logarithm of firm age, calculated as the number of years the firm is listed with a non-missing stock price on CRSP.

Additional variables used in alternative investment efficiency model specification (Source: Compustat, Institutional Shareholder Services (ISS), Thomson Reuters, IBES)	
E-index	is the entrenchment index (E-index) of Bebchuck et al. (2009). We construct the annual values of the E-index ourselves for years after 2006, using data from the Institutional Shareholder Services (ISS). Values for the E-index until 2006 are downloaded directly from the website of Lucian A. Bebchuk (http://www.law. harvard.edu/faculty/bebchuk/). When this index is missing, it is assigned the value of 0, while its value is multiplied by minus one so that higher values imply lower anti-takeover protection, and therefore increased market discipline.

INST	is the percentage of firm shares held by institutional investors, using the average value for the four quarters in a fiscal year, from Thomson Reuters 13F.
AQ	is a proxy for accounting quality, calculated as the standard deviation of the firm-level residuals from the Dechow and Dichev (2002) model during years *t-5* to *t-1* multiplied by minus one, so that the value of the proxy increases with accounting quality. This model is a regression of working capital accruals on lagged, current, and future cash flows, plus the change in revenue and PPE: $Working\ Capital\ Accruals_{i,t} = b_0 + b_1 CFO_{i,t-1} + b_2 CFO_{i,t} + b_3 CFO_{i,t+1} + b_4 \Delta Sales_{i,t} + b_5 PPE_{i,t} + +\varepsilon_{i,t}$ A firm's total working capital accruals are calculated as the change in non-cash current assets minus the change in current non-interest-bearing liabilities. $\Delta Sales_{i,t}$ is change in sales with reference to the previous year, CFO stands for cash flow from operations, and $PPE_{i,t}$ is gross property, plant and equipment. All variables are scaled by average total assets. The model is estimated cross-sectionally for each FF48 industry with at least 20 observations in a year.
LogAnalysts	is the logarithm of the average number of analysts following the firm and issuing one-year ahead EPS forecasts during a year, from the IBES summary file.
Ind K-structure	is the mean *Lev* for firms in the same FF48 industry for the year.

Variables used in controls for endogeneity (Source: IvyDB Optionmetrics, CRSP)	
Moneyness	is the annual average absolute difference between a stock's market price and the option's strike price.
OpenInterest	is the average open interest across all options on a stock throughout the fiscal year.

Variables used for the examination of H3 and supplementary analyses (Source: Compustat, Thomson Reuters, IBES, World Bank)	
InstitOwn.-top five_H-L	is a binary indicator of whether a firm falls above or below the sample-year median for institutional blockholders (>=5%) expressed as percentage of market capitalization at fiscal year-end, from Thomson Reuters 13F.
Rating	is a binary indicator taking the value of one if the firm has an S&P rating for its long-term debt in a year, and zero otherwise.
BusSegments_H-L	is a binary indicator of whether a firm falls above or below the sample-year median for its number of business segments in which the firm operates in a given year, from Compustat..
GeoSegments_H-L	is a binary indicator of whether a firm falls above or below the sample-year median for its number of geographical segments in which the firm operates in a given year, from Compustat.
Unexp_Inv_H-L	is a binary indicator of whether a firm falls above or below the sample-year median for firm-year unexpected investment. Unexpected investment is calculated as in Chen et al. (2017b), by estimating a cross-sectional regression of total investment (*INV*) in year *t* on lagged Tobin's Q (*MB* variable described in this Appendix) for each year and FF48 industry with at least 20 observations in a year. Deviations from the predicted level of investment, as reflected in the error terms of the model for each firm signify unexpected investment.
CDS	is a binary indicator taking the value of one if a firm has CDS traded in any year during the sample period based on data from Thomson Reuters, and zero otherwise.

Table 1 Descriptive statistics

	Q1	*Mean*	*Median*	*Q3*	*StDev*	*N*
Investment efficiency-related variables						
$INV_{i,t}$	4.343	13.846	8.918	17.130	17.741	34,090
$Capex_{i,t}$	1.695	5.722	3.635	7.093	7.144	34,090
$NonCapex_{i,t}$	0.000	8.379	2.135	10.451	16.283	34,090
$INV\_INEFF_{i,t}$	-8.674	-1.691	-3.397	1.576	15.261	34,090
$INV\_INEFF_{i,t}^{GO}$	-8.433	-1.834	-3.459	1.420	15.307	29,050
$INV\_INEFF_{i,t}^{GO,M}$	-8.011	-0.999	-3.113	1.996	14.960	34,044
$Capex\_INEFF_{i,t}$	-2.656	-0.195	-0.964	1.110	5.671	34,090
$Capex\_INEFF_{i,t}^{GO}$	-2.632	-0.147	-0.907	1.339	5.768	29,050
$Capex\_INEFF_{i,t}^{GO,M}$	-2.675	-0.243	-1.013	1.083	5.636	34,044
$NonCapex\_INEFF_{i,t}$	-6.303	-1.405	-2.676	-0.150	13.540	34,090
$NonCapex\_INEFF_{i,t}^{GO}$	-6.284	-1.611	-2.645	-0.296	13.502	29,050
$NonCapex\_INEFF_{i,t}^{GO,M}$	-5.766	-0.697	-2.381	0.095	13.145	34,044
$OverFirm_{i,t}$	0.350	0.509	0.500	0.650	0.200	34,010
Options-related variables						
$LnOptVol_{i,t}$	0.011	0.360	0.064	0.373	0.653	33,004
$LnOptNon\$Vol_{i,t}$	9.069	10.705	10.646	12.426	2.397	33,004
$LnVolCalls_{i,t}$	0.007	0.271	0.039	0.248	0.538	32,958
$LnVolPuts_{i,t}$	0.003	0.191	0.021	0.147	0.417	32,872
$LnOptVolDelta_{i,t}$	7.167	8.760	8.818	10.461	2.433	28,679
Control variables for baseline model specification						
$CFOSales_{i,t}$	0.047	-0.236	0.114	0.207	4.387	34,045
$Dividend_{i,t}$	0.000	0.510	1.000	1.000	0.500	34,090
$Lev_{i,t}$	0.012	0.196	0.135	0.306	0.210	34,011
$Loss_{i,t}$	0.000	0.254	0.000	1.000	0.435	34,090
$MB_{i,t}$	1.120	2.037	1.526	2.319	1.706	33,644
$OperCycle_{i,t}$	4.213	4.723	4.683	5.145	1.032	33,925
$LogTA_{i,t}$	6.128	7.458	7.379	8.702	1.906	34,089
$Slack_{i,t}$	0.115	9.628	0.582	2.757	312.301	34,065
$Tangibility_{i,t}$	0.075	0.276	0.186	0.432	0.249	34,076
$ZScore_{i,t}$	0.502	1.029	1.070	1.703	1.523	34,045
$\sigma(CFO)_{i,t}$	0.024	0.059	0.042	0.072	0.062	34,090
$\sigma(Sales)_{i,t}$	0.072	0.211	0.144	0.269	0.224	34,090
$\sigma(I)_{i,t}$	0.022	0.115	0.053	0.119	0.261	34,090
$LogAge_{i,t}$	9.000	22.064	16.000	29.000	18.204	33,926
Variables used in channel analyses and alternative investment efficiency model specification						
$E-index_{i,t}$	-4.000	-3.363	-4.000	-2.000	1.379	17,722
$INST_{i,t}$	0.467	0.664	0.706	0.862	2.064	32,391
$AQ_{i,t}$	-0.065	-0.054	-0.041	-0.025	0.052	31,522
$LogAnalysts_{i,t}$	0.602	0.842	0.872	1.130	0.373	32,523
$Ind\ K-structure_{i,t}$	0.087	0.186	0.151	0.255	0.120	34,090
Variables used as instruments in endogeneity						
$Moneyness_{i,t}$	1.956	5.983	3.363	6.044	9.843	33,004
$OpenInterest_{i,t}$	88.466	745.544	258.458	709.662	2017.997	33,004
Variables used in channel analyses and robustness controls						
$HP\ index_{i,t}$	-3.279	-2.714	-2.712	-2.235	0.624	30,282
$KZ\ index_{i,t}$	-8.245	-12.699	-1.771	0.568	65.506	33,672

$InstitOwn - top\ five_{i,t}$	0.046	0.317	0.098	0.225	2.109	32,394
$BusSegment_{i,t}$	1.000	2.877	3.000	4.000	2.058	33,187
$GeoSegment_{i,t}$	2.000	3.378	3.000	4.000	2.700	28,565
$Unexp\_Inv_{i,t}$	-8.675	-1.961	-3.551	1.294	15.957	34,055
	With	Without				
$Credit\ Rating$	13,943	20,147				34,090
CDS	5,551	28,539				34,090

Note: This table reports descriptive statistics for all sample firm-year observations during 1996-2019, with data availability for our baseline model specification (equation (4)). Detailed variable definitions are provided in Appendix A.

Table 2, Panel A Effect of options volume on investment inefficiency, panel OLS estimates

	Dependent variable: $INV\_INEFF_{i,t+1}$			Dependent variable:	
Independent variables	Entire sample	Over-investment sample	Under-investment sample	$Capex\_INEFF_{i,t+1}$	$NonCapex\_INEFF_{i,t+1}$
$\boldsymbol{LnOptVol_{i,t}}$	**-0.9161*****	**-0.2107**	**-0.9402*****	**-0.2028**	**-0.6861*****
	(0.2703)	**(0.3837)**	**(0.2208)**	**(0.1380)**	**(0.2409)**
$Lev_{i,t}$	-4.5977***	0.9557	0.6345	-2.4537***	-1.7502***
	(0.6639)	(1.4692)	(0.4481)	(0.3911)	(0.5641)
$LogTA_{i,t}$	-0.4518***	-1.2217***	0.2382***	-0.1254**	-0.3533***
	(0.1137)	(0.1918)	(0.0879)	(0.0572)	(0.0988)
$MB_{i,t}$	1.1528***	0.9204***	-0.2302***	0.4756***	0.6886***
	(0.1374)	(0.1878)	(0.0735)	(0.0363)	(0.1262)
$\sigma(I)_{i,t}$	1.1570***	2.5392***	-1.3235***	0.2528	0.9712***
	(0.4275)	(0.5522)	(0.2822)	(0.1752)	(0.3757)
$\sigma(CFO)_{i,t}$	3.6277	7.9775*	-5.7600***	2.4708***	1.0622
	(2.9139)	(4.2109)	(1.5193)	(0.8324)	(2.6406)
$\sigma(Sales)_{i,t}$	2.0893***	-0.0863	0.8252**	-0.5263*	2.4614***
	(0.7086)	(1.1177)	(0.3935)	(0.2983)	(0.6235)
$Tangibility_{i,t}$	6.6162***	-3.1477***	3.1341***	7.6218***	-0.7313
	(0.6011)	(0.9986)	(0.4182)	(0.4288)	(0.4615)
$OperCycle_{i,t}$	-0.4531***	-0.9828***	0.4803***	0.5049***	-0.9333***
	(0.1460)	(0.2525)	(0.0946)	(0.0514)	(0.1293)
$Loss_{i,t}$	-2.4560***	-3.2707***	-0.8234***	-0.8024***	-1.5129***
	(0.3229)	(0.6430)	(0.1602)	(0.1148)	(0.2927)
$CFOSales_{i,t}$	-0.0499	-0.0444	-0.0001	0.0406***	-0.0894*
	(0.0564)	(0.0610)	(0.0190)	(0.0092)	(0.0515)
$Dividend_{i,t}$	-0.2100	-0.3753	0.8670***	-0.9133***	0.6377**
	(0.3058)	(0.5336)	(0.2142)	(0.1437)	(0.2707)
$Slack_{i,t}$	-0.0042***	-0.0012	-0.0034***	-0.0003	-0.0040***
	(0.0012)	(0.0009)	(0.0006)	(0.0002)	(0.0012)
$ZScore_{i,t}$	-1.0203***	-1.4134***	0.3006***	0.3031***	-1.3257***
	(0.2265)	(0.2949)	(0.0862)	(0.0438)	(0.2086)
$LogAge_{i,t}$	-0.0132*	-0.0120	-0.0031	-0.0177***	0.0054
	(0.0073)	(0.0126)	(0.0057)	(0.0043)	(0.0065)
Intercept	-0.2310	27.0659***	-14.9751***	-5.0623***	4.6594***
	(1.4011)	(2.5029)	(0.8177)	(0.5333)	(1.2462)
Year FE	YES	YES	YES	YES	YES
N	34,090	10,441	23,649	34,090	34,090
R-square	0.0622	0.0915	0.1117	0.1207	0.0452
No of firms	4,860	3,121	4,306	4,860	4,860

Note: This table reports OLS estimation results of equation (4) that is shown in the main text. The second column reports results for the entire sample, while the third (respectively fourth) column reports results for the over-investment (respectively under-investment) subsample, $INV\_INEFF_{i,t+1} \geq 0$ (respectively $INV\_INEFF_{i,t+1} < 0$). The fifth (respectively sixth) column reports results for $Capex\_INEFF_{i,t}$ (respectively $NonCapex\_INEFF_{i,t}$) as the dependent variable. Panels A, B, and C of the Table report relevant results when defining investment inefficiency as $INV\_INEFF_{i,t+1}$, $INV\_INEFF^{GO}_{i,t+1}$ and $INV\_INEFF^{GO,M}_{i,t+1}$ respectively. The sample selection process is described in Section 3.1. All variables are defined in Appendix A. Standard errors double-clustered at the firm and the industry level (FF48 sectors) are reported in parentheses. ***, ** and * indicate statistical significance at 1%, 5% and 10% respectively.

Table 2, Panel B Effect of options volume on investment inefficiency, panel OLS estimates

	Dependent variable: $INV\_INEFF^{GO}_{i,t+1}$			Dependent variable:	
Independent variables	Entire sample	Over-investment sample	Under-investment sample	$Capex\_INEFF^{GO}_{i,t+1}$	$NonCapex\_INEFF^{GO}_{i,t+1}$
$\boldsymbol{LnOptVol_{i,t}}$	**-0.7802*** **	**0.0033**	**-1.0044*** **	**-0.2154**	**-0.5524** **
	(0.2796)	**(0.4443)**	**(0.2161)**	**(0.1339)**	**(0.2501)**
$Lev_{i,t}$	-0.1542	-2.1688*	2.9279***	-1.8475***	1.7966***
	(0.7275)	(1.2250)	(0.4786)	(0.3960)	(0.6134)
$LogTA_{i,t}$	-0.6558***	-1.3388***	0.2359***	-0.0670	-0.6217***
	(0.1155)	(0.1984)	(0.0891)	(0.0538)	(0.1033)
$MB_{i,t}$	1.1103***	0.8406***	-0.2279***	0.5310***	0.5931***
	(0.1698)	(0.2467)	(0.0785)	(0.0487)	(0.1544)
$\sigma(I)_{i,t}$	0.6949	3.2232***	-1.2118***	0.2340	0.4827
	(0.4567)	(0.7383)	(0.2862)	(0.1885)	(0.3852)
$\sigma(CFO)_{i,t}$	6.5919**	5.9403	-3.0303*	4.4631***	2.3806
	(3.2223)	(4.8030)	(1.7488)	(1.1786)	(2.9306)
$\sigma(Sales)_{i,t}$	2.0894***	-0.5862	1.1106**	-0.9164***	2.8552***
	(0.6923)	(1.1245)	(0.4457)	(0.3419)	(0.5868)
$Tangibility_{i,t}$	5.8797***	-4.0547***	2.5263***	6.3930***	-0.3792
	(0.5989)	(1.0297)	(0.4336)	(0.4400)	(0.4589)
$OperCycle_{i,t}$	-0.8811***	-0.8266***	-0.2303*	0.3828***	-1.2438***
	(0.1888)	(0.2972)	(0.1348)	(0.0754)	(0.1655)
$Loss_{i,t}$	-2.2677***	-3.7541***	-0.4956***	-0.5489***	-1.6370***
	(0.3021)	(0.6349)	(0.1735)	(0.1248)	(0.2668)
$CFOSales_{i,t}$	-0.1050**	0.0131	-0.0420	0.0423***	-0.1479***
	(0.0516)	(0.0402)	(0.0256)	(0.0140)	(0.0474)
$Dividend_{i,t}$	-0.3359	-0.1552	0.6713***	-1.0549***	0.7046**
	(0.3088)	(0.5538)	(0.2136)	(0.1555)	(0.2728)
$Slack_{i,t}$	-0.0019	0.0007	-0.0013***	-0.0005**	-0.0014
	(0.0012)	(0.0012)	(0.0003)	(0.0002)	(0.0011)
$ZScore_{i,t}$	-0.3088*	-1.4584***	0.5812***	0.3455***	-0.6848***
	(0.1876)	(0.2410)	(0.1126)	(0.0532)	(0.1693)
$LogAge_{i,t}$	-0.0061	-0.0218*	0.0086	-0.0114***	0.0055
	(0.0069)	(0.0121)	(0.0054)	(0.0039)	(0.0062)
Intercept	2.2880	28.1268***	-11.9992***	-4.2456***	6.6152***
	(1.6116)	(2.7489)	(1.0171)	(0.6405)	(1.4414)
Year FE	YES	YES	YES	YES	YES
N	29,050	8,851	20,199	29,050	29,050
R-square	0.0455	0.0790	0.1063	0.0945	0.0310
No of firms	4,290	2,843	3,811	4,290	4,290

Table 2, Panel C Effect of options volume on investment inefficiency, panel OLS estimates

	Dependent variable: $INV\_INEFF^{GO,M}_{i,t+1}$			Dependent variable:	
Independent variables	Entire sample	Over-investment sample	Under-investment sample	$Capex\_INEFF^{GO,M}_{i,t+1}$	$NonCapex\_INEFF^{GO,M}_{i,t+1}$
$\boldsymbol{LnOptVol_{i,t}}$	**-0.7407******	**-0.1757**	**-0.7591******	**-0.1929**	**-0.5179******
	(0.2361)	**(0.3571)**	**(0.1600)**	**(0.1395)**	**(0.1972)**
$Lev_{i,t}$	-5.3518***	0.4494	-0.4464	-2.1569***	-2.7165***
	(0.6353)	(1.3276)	(0.4010)	(0.3926)	(0.5257)
$LogTA_{i,t}$	-0.3276***	-1.1486***	0.3259***	-0.1578***	-0.2071**
	(0.1034)	(0.1806)	(0.0701)	(0.0577)	(0.0865)
$MB_{i,t}$	1.3963***	0.8992***	0.0081	0.4849***	0.9170***
	(0.1408)	(0.1762)	(0.0627)	(0.0367)	(0.1298)
$\sigma(I)_{i,t}$	1.4783***	2.5573***	-0.9544***	0.1791	1.3520***
	(0.4292)	(0.5441)	(0.2443)	(0.1745)	(0.3769)
$\sigma(CFO)_{i,t}$	3.2472	9.2613**	-6.4197***	2.5007***	0.9284
	(2.9175)	(3.8720)	(1.4520)	(0.8343)	(2.6574)
$\sigma(Sales)_{i,t}$	1.2508*	-0.2997	0.1728	-0.3503	1.4542**
	(0.6802)	(1.0013)	(0.3902)	(0.2970)	(0.5937)
$Tangibility_{i,t}$	5.6978***	-2.6583***	2.4005***	7.1811***	-1.3592***
	(0.5749)	(0.9527)	(0.3751)	(0.4284)	(0.4268)
$OperCycle_{i,t}$	-0.2690**	-1.0764***	0.6559***	0.4859***	-0.7078***
	(0.1341)	(0.2274)	(0.0793)	(0.0518)	(0.1173)
$Loss_{i,t}$	-2.5706***	-3.1012***	-1.0229***	-0.6845***	-1.7474***
	(0.3135)	(0.5807)	(0.1549)	(0.1152)	(0.2803)
$CFOSales_{i,t}$	-0.0053	-0.0351	0.0561**	0.0310***	-0.0337
	(0.0602)	(0.0627)	(0.0222)	(0.0088)	(0.0546)
$Dividend_{i,t}$	-0.8414***	-0.3999	0.4383**	-0.9015***	0.0116
	(0.2842)	(0.5042)	(0.1741)	(0.1435)	(0.2452)
$Slack_{i,t}$	-0.0033**	-0.0007	-0.0030***	-0.0003	-0.0027*
	(0.0016)	(0.0016)	(0.0006)	(0.0002)	(0.0016)
$ZScore_{i,t}$	-0.7062***	-1.5327***	0.4331***	0.2328***	-0.9464***
	(0.2182)	(0.2497)	(0.0973)	(0.0449)	(0.1989)
$LogAge_{i,t}$	-0.0176***	-0.0063	-0.0057	-0.0186***	0.0023
	(0.0067)	(0.0121)	(0.0046)	(0.0043)	(0.0056)
Intercept	-0.4237	26.8658***	-15.1316***	-4.4683***	3.8595***
	(1.3352)	(2.2705)	(0.7002)	(0.5350)	(1.1777)
Year FE	YES	YES	YES	YES	YES
N	34,044	10,964	23,080	34,044	34,044
R-square	0.0657	0.0913	0.1169	0.1207	0.0437
No of firms	4,857	3,230	4,286	4,857	4,857

Table 3 Effect of options volume on over and under-investment, panel OLS estimates

Independent variables	Dependent variable: $INV_{i,t+1}$	Dependent variable: $Capex_{i,t+1}$	Dependent variable: $NonCapex_{i,t+1}$
$\boldsymbol{LnOptVol_{i,t}}$	**1.8798*** **	**-0.2530**	**2.1217*** **
	(0.5821)	**(0.2836)**	**(0.5021)**
$\boldsymbol{LnOptVol_{i,t} \times OverFirm_{i,t}}$	**-3.3961*** **	**0.6758**	**-4.0242*** **
	(1.0374)	**(0.5028)**	**(0.9029)**
Wald test, sum of coefficients $\boldsymbol{LnOptVol_{i,t}}$ ***and*** $\boldsymbol{LnVOptol_{i,t} \times OverFirm_{i,t}}$***, F-statistic***	**7.06**	**2.50**	**14.22**
p-value	**[0.0079]**	**[0.1143]**	**[0.0002]**
$INST_{i,t}$	0.0880	0.1153	-0.1277
	(0.3373)	(0.1516)	(0.2523)
$INST_{i,t} \times OverFirm_{i,t}$	-0.2294	-0.2272	0.2062
	(0.6915)	(0.3059)	(0.5258)
$LogAnalysts_{i,t}$	2.2249**	0.9971*	1.3693*
	(0.9419)	(0.5102)	(0.8050)
$LogAnalysts_{i,t} \times OverFirm_{i,t}$	1.9496	-0.7514	2.4776
	(1.7463)	(0.8784)	(1.5298)
$AQ_{i,t}$	-8.0281	-2.6513	-5.5463
	(9.3854)	(3.5143)	(8.7549)
$AQ_{i,t} \times OverFirm_{i,t}$	21.1154	5.1670	16.5933
	(14.2530)	(5.4930)	(13.3441)
$OverFirm_{i,t}$	4.3797**	3.4920***	0.7168
	(1.6971)	(0.8003)	(1.4854)
$Ind\ K-structure_{i,t}$	-17.1003***	-6.4683***	-10.4941***
	(1.4247)	(0.8154)	(1.1962)
$LogTA_{i,t}$	-1.2597***	-0.1512**	-1.1417***
	(0.1291)	(0.0634)	(0.1114)
$MB_{i,t}$	1.9113***	0.4159***	1.4619***
	(0.1836)	(0.0323)	(0.1792)
$\sigma(I)_{i,t}$	2.5848***	1.0968***	1.5515***
	(0.5284)	(0.2883)	(0.4590)
$\sigma(CFO)_{i,t}$	27.0123***	5.4243***	21.4581***
	(3.5073)	(1.1974)	(3.2017)
$\sigma(Sales)_{i,t}$	-1.5971**	0.1111	-1.7414**
	(0.8063)	(0.2227)	(0.7489)
$Tangibility_{i,t}$	6.3732***	19.0932***	-11.8630***
	(0.7474)	(0.5984)	(0.5521)
$OperCycle_{i,t}$	-0.6234***	0.2281***	-0.8584***
	(0.2228)	(0.0744)	(0.2095)
$Loss_{i,t}$	-2.3503***	-0.9984***	-1.1488***
	(0.4303)	(0.1260)	(0.3886)
$CFOSales_{i,t}$	-0.0963**	0.0464***	-0.1416***
	(0.0429)	(0.0105)	(0.0411)
$Dividend_{i,t}$	-1.6768***	-0.9815***	-0.7319***
	(0.3175)	(0.1527)	(0.2806)
$Slack_{i,t}$	-0.0023***	-0.0005*	-0.0017***
	(0.0007)	(0.0003)	(0.0005)
$ZScore_{i,t}$	-2.2712***	0.3114***	-2.5379***
	(0.3108)	(0.0505)	(0.2852)

$LogAge_{i,t}$	-0.0067	-0.0197***	0.0133**
	(0.0068)	(0.0035)	(0.0063)
Intercept	23.9225***	0.2541	24.1218***
	(2.0805)	(0.7761)	(1.9037)
Year FE	YES	YES	YES
N	30,059	30,059	30,059
R-square	0.1900	0.3730	0.2256
No of firms	4,206	4,206	4,206

Note: This table reports OLS estimation results of equation (5) that is shown in the main text. The sample selection process is described in Section 3.1. All variables are defined in Appendix A. The null hypothesis of the Wald test is that the sum of the coefficients of $LnVol_{i,t}$ and $LnVol_{i,t} \times OverFirm_{i,t}$ is zero. *P-values* of the Wald test *F-statistic* are reported in square brackets. Standard errors double-clustered at the firm and the industry level (FF48 sectors) are reported in parentheses. ***, ** and * indicate statistical significance at 1%, 5% and 10% respectively.

Table 4, Panel A Effect of options volume on investment efficiency, two-step GMM IV estimates

Effect on investment inefficiency, two-step GMM IV estimates					
	Dependent variable: $INV\_INEFF_{i,t+1}$			Dependent variable:	
Independent variables	Entire sample	Over-investment sample	Under-investment sample	$Capex\_INEFF_{i,t+1}$	$NonCapex\_INEFF_{i,t+1}$
$\boldsymbol{LnOptVol_{i,t}}$	**-1.3424****	**-0.3242**	**-1.4874*****	**-0.0669**	**-1.1420****
	(0.5663)	**(0.5439)**	**(0.4880)**	**(0.2346)**	**(0.4791)**
$Lev_{i,t}$	-4.8670***	0.8562	0.3411	-2.3802***	-2.0391***
	(0.7329)	(1.5184)	(0.5008)	(0.4043)	(0.6188)
$LogTA_{i,t}$	-0.3465**	-1.1899***	0.3671***	-0.1560**	-0.2386*
	(0.1615)	(0.2282)	(0.1311)	(0.0731)	(0.1381)
$MB_{i,t}$	1.1833***	0.9270***	-0.1803**	0.4642***	0.7094***
	(0.1420)	(0.1873)	(0.0830)	(0.0386)	(0.1293)
$\sigma(I)_{i,t}$	1.1641***	2.5381***	-1.3130***	0.2571	0.9893***
	(0.4264)	(0.5513)	(0.2794)	(0.1751)	(0.3748)
$\sigma(CFO)_{i,t}$	4.0749	8.0714*	-5.0914***	2.2983***	1.4250
	(2.9622)	(4.2178)	(1.6105)	(0.8622)	(2.6681)
$\sigma(Sales)_{i,t}$	2.1780***	-0.0607	0.9325**	-0.5296*	2.5530***
	(0.7122)	(1.1165)	(0.3973)	(0.3010)	(0.6281)
$Tangibility_{i,t}$	6.6509***	-3.1474***	3.1914***	7.6400***	-0.6512
	(0.6020)	(0.9971)	(0.4200)	(0.4286)	(0.4623)
$OperCycle_{i,t}$	-0.4673***	-0.9847***	0.4613***	0.5164***	-0.9482***
	(0.1471)	(0.2517)	(0.0959)	(0.0518)	(0.1302)
$Loss_{i,t}$	-2.3910***	-3.2518***	-0.7419***	-0.8132***	-1.4507***
	(0.3313)	(0.6420)	(0.1732)	(0.1170)	(0.2990)
$CFOSales_{i,t}$	-0.0508	-0.0446	-0.0012	0.0408***	-0.0912*
	(0.0563)	(0.0609)	(0.0189)	(0.0092)	(0.0514)
$Dividend_{i,t}$	-0.2865	-0.3951	0.7739***	-0.9165***	0.5358*
	(0.3119)	(0.5363)	(0.2178)	(0.1466)	(0.2754)
$Slack_{i,t}$	-0.0042***	-0.0012	-0.0034***	-0.0003	-0.0040***
	(0.0012)	(0.0009)	(0.0006)	(0.0002)	(0.0012)
$ZScore_{i,t}$	-1.0207***	-1.4146***	0.2961***	0.3013***	-1.3038***
	(0.2258)	(0.2934)	(0.0855)	(0.0439)	(0.2075)
$LogAge_{i,t}$	-0.0123*	-0.0120	-0.0014	-0.0173***	0.0058
	(0.0072)	(0.0125)	(0.0056)	(0.0043)	(0.0064)
Intercept	-0.9123	26.8712***	-15.8473***	-4.8898***	3.9089***
	(1.5618)	(2.6031)	(1.0217)	(0.6035)	(1.3759)
Year FE	YES	YES	YES	YES	YES
Hansen's J statistic	0.024	0.001	0.015	5.274	1.405
p-value	[0.8764]	[0.9795]	[0.9036]	[0.0216]	[0.2360]
N	34,090	10,441	23,649	34,090	34,090
R-square	0.0621	0.0915	0.1101	0.1205	0.0449
No of firms	4,860	3,121	4,306	4,860	4,860

Note: This Table reports the results of re-estimating equation (4) reported in text using a two-step, generalized method of moments instrumental variable approach. To achieve identification, the following excluded instrumental variables (IVs) are employed: $Moneyness_{i,t}$ and $OpenInterest_{i,t}$. Under *Hansen's J statistic* we report a heteroskedasticity-consistent test of overidentifying restrictions in GMM estimation; its joint null hypothesis is that the instruments are valid, and the excluded instruments are correctly excluded from the estimated equation. Panels A, B, and C of the Table report relevant results when defining investment inefficiency as $INV\_INEFF_{i,t+1}$, $INV\_INEFF^{GO}_{i,t+1}$ and $INV\_INEFF^{GO,M}_{i,t+1}$ respectively. The sample selection process is described in Section 3.1. All variables are defined in Appendix A. Standard errors double-clustered at the firm and the industry level (FF48 sectors) are reported in parentheses. ***, ** and * indicate statistical significance at 1%, 5% and 10% respectively.

Table 4, Panel B Effect of options volume on investment efficiency, two-step GMM IV estimates

Effect on investment inefficiency, two-step GMM IV estimates					
	Dependent variable: $INV\_INEFF^{GO}_{i,t+1}$			Dependent variable:	
Independent variables	Entire sample	Over-investment sample	Under-investment sample	$Capex\_INEFF^{GO}_{i,t+1}$	$NonCapex\_INEFF^{GO}_{i,t+1}$
$\boldsymbol{LnOptVol_{i,t}}$	**-1.2392****	**-0.3496**	**-1.8037*****	**-0.1479**	**-1.0504****
	(0.5979)	**(0.6509)**	**(0.4993)**	**(0.2351)**	**(0.5080)**
$Lev_{i,t}$	-0.4188	-2.3266*	2.5042***	-1.8501***	1.4823**
	(0.7936)	(1.2641)	(0.5310)	(0.4035)	(0.6709)
$LogTA_{i,t}$	-0.5409***	-1.2594***	0.4304***	-0.0825	-0.4939***
	(0.1690)	(0.2415)	(0.1374)	(0.0723)	(0.1468)
$MB_{i,t}$	1.1500***	0.8763***	-0.1477	0.5216***	0.6226***
	(0.1753)	(0.2468)	(0.0902)	(0.0507)	(0.1586)
$\sigma(I)_{i,t}$	0.7046	3.2350***	-1.1959***	0.2295	0.4936
	(0.4562)	(0.7367)	(0.2828)	(0.1883)	(0.3846)
$\sigma(CFO)_{i,t}$	7.2021**	6.3559	-1.9453	4.3523***	2.9489
	(3.2863)	(4.8453)	(1.8641)	(1.2109)	(2.9702)
$\sigma(Sales)_{i,t}$	2.1854***	-0.5289	1.2675***	-0.9016***	2.9639***
	(0.6986)	(1.1190)	(0.4501)	(0.3459)	(0.5933)
$Tangibility_{i,t}$	5.9121***	-4.0464***	2.6113***	6.4216***	-0.3088
	(0.5987)	(1.0286)	(0.4350)	(0.4400)	(0.4593)
$OperCycle_{i,t}$	-0.8814***	-0.8223***	-0.2373*	0.3857***	-1.2430***
	(0.1883)	(0.2969)	(0.1343)	(0.0753)	(0.1652)
$Loss_{i,t}$	-2.1935***	-3.7304***	-0.3743**	-0.5549***	-1.5616***
	(0.3121)	(0.6440)	(0.1877)	(0.1282)	(0.2752)
$CFOSales_{i,t}$	-0.1053**	0.0141	-0.0428*	0.0421***	-0.1486***
	(0.0514)	(0.0400)	(0.0257)	(0.0139)	(0.0472)
$Dividend_{i,t}$	-0.4073	-0.2143	0.5444**	-1.0639***	0.6163**
	(0.3148)	(0.5564)	(0.2202)	(0.1590)	(0.2775)
$Slack_{i,t}$	-0.0019	0.0007	-0.0013***	-0.0005**	-0.0014
	(0.0012)	(0.0012)	(0.0003)	(0.0002)	(0.0011)
$ZScore_{i,t}$	-0.3152*	-1.4621***	0.5777***	0.3437***	-0.6754***
	(0.1872)	(0.2401)	(0.1108)	(0.0533)	(0.1686)
$LogAge_{i,t}$	-0.0049	-0.0211*	0.0106**	-0.0113***	0.0061
	(0.0068)	(0.0121)	(0.0052)	(0.0039)	(0.0060)
Intercept	1.4490	27.5627***	-13.4546***	-4.1242***	5.6820***
	(1.8081)	(2.9167)	(1.2336)	(0.7273)	(1.5950)
Year FE	YES	YES	YES	YES	YES
Hansen's J statistic	0.043	0.422	0.328	0.070	0.626
p-value	[0.8350]	[0.5158]	[0.5669]	[0.7920]	[0.4288]
N	29,050	8,851	20,199	29,050	29,050
R-square	0.0452	0.0789	0.1028	0.0944	0.0442
No of firms	4,290	2,843	3,811	4,290	4,290

Table 4, Panel C Effect of options volume on investment efficiency, two-step GMM IV estimates

Effect on investment inefficiency, two-step GMM IV estimates					
	Dependent variable: $INV\_INEFF_{i,t+1}^{GO,M}$			Dependent variable:	
Independent variables	Entire sample	Over-investment sample	Under-investment sample	$Capex\_INEFF_{i,t+1}^{GO,M}$	$NonCapex\_INEFF_{i,t+1}^{GO,M}$
$\boldsymbol{LnOptVol_{i,t}}$	**-1.0630****	**-0.2089**	**-1.2619*****	**0.0031**	**-0.7757****
	(0.4811)	**(0.5462)**	**(0.3626)**	**(0.2368)**	**(0.3695)**
$Lev_{i,t}$	-5.5692***	0.4261	-0.7081	-2.0569***	-2.9186***
	(0.6868)	(1.3620)	(0.4333)	(0.4048)	(0.5621)
$LogTA_{i,t}$	-0.2439*	-1.1410***	0.4417***	-0.2015***	-0.1307
	(0.1426)	(0.2225)	(0.0991)	(0.0735)	(0.1150)
$MB_{i,t}$	1.4115***	0.9020***	0.0528	0.4691***	0.9074***
	(0.1439)	(0.1772)	(0.0695)	(0.0391)	(0.1312)
$\sigma(I)_{i,t}$	1.4977***	2.5580***	-0.9562***	0.1871	1.3865***
	(0.4283)	(0.5431)	(0.2427)	(0.1743)	(0.3762)
$\sigma(CFO)_{i,t}$	3.5148	9.2890**	-5.8362***	2.2446***	0.9683
	(2.9526)	(3.9056)	(1.5071)	(0.8624)	(2.6694)
$\sigma(Sales)_{i,t}$	1.3266*	-0.2933	0.2657	-0.3588	1.5132**
	(0.6817)	(0.9982)	(0.3915)	(0.2999)	(0.5955)
$Tangibility_{i,t}$	5.7344***	-2.6579***	2.4578***	7.2025***	-1.2812***
	(0.5754)	(0.9510)	(0.3763)	(0.4281)	(0.4275)
$OperCycle_{i,t}$	-0.2819**	-1.0779***	0.6369***	0.5010***	-0.7142***
	(0.1349)	(0.2266)	(0.0798)	(0.0522)	(0.1177)
$Loss_{i,t}$	-2.5260***	-3.0991***	-0.9606***	-0.7007***	-1.7162***
	(0.3199)	(0.5858)	(0.1610)	(0.1172)	(0.2843)
$CFOSales_{i,t}$	-0.0063	-0.0351	0.0549**	0.0315***	-0.0355
	(0.0601)	(0.0626)	(0.0221)	(0.0088)	(0.0545)
$Dividend_{i,t}$	-0.9054***	-0.4054	0.3483*	-0.9028***	-0.0592
	(0.2898)	(0.5096)	(0.1785)	(0.1471)	(0.2491)
$Slack_{i,t}$	-0.0032**	-0.0007	-0.0029***	-0.0003	-0.0026*
	(0.0016)	(0.0016)	(0.0006)	(0.0002)	(0.0016)
$ZScore_{i,t}$	-0.6973***	-1.5342***	0.4303***	0.2302***	-0.9069***
	(0.2175)	(0.2489)	(0.0968)	(0.0449)	(0.1978)
$LogAge_{i,t}$	-0.0171**	-0.0062	-0.0046	-0.0181***	0.0024
	(0.0066)	(0.0120)	(0.0045)	(0.0044)	(0.0056)
Intercept	-0.9577	26.8247***	-15.8912***	-4.2121***	3.3546***
	(1.4657)	(2.4034)	(0.8261)	(0.6044)	(1.2717)
Year FE	YES	YES	YES	YES	YES
Hansen's J statistic	0.626	0.005	1.769	0.494	0.061
p-value	[0.4287]	[0.9411]	[0.1835]	[0.4823]	[0.8053]
N	34,044	10,964	23,080	34,044	34,044
R-square	0.0656	0.0915	0.1152	0.1118	0.0435
No of firms	4,857	3,230	4,286	4,857	4,857

Table 5 Effect of options volume, propensity score matching analysis

Panel A Propensity score matching

Variables	Treatment (Firms with high options volume)	Control (Firms with low options volume)	*t-test*
$\boldsymbol{INV\_INEFF_{i,t}}$	**-0.2481**	**-1.8921**	**6.91*** **
$\boldsymbol{Capex\_INEFF_{i,t}}$	**0.4124**	**-0.4174**	**8.80*** **
$\boldsymbol{NonCapex\_INEFF_{i,t}}$	**-0.7017**	**-1.3991**	**3.38*** **
$Lev_{i,t}$	0.2024	0.2024	-0.00
$LogTA_{i,t}$	8.2267	8.2269	0.01
$MB_{i,t}$	2.2540	2.2528	0.04
$\sigma(I)_{i,t}$	0.1253	0.1268	-0.18
$\sigma(CFO)_{i,t}$	0.0556	0.0559	-0.02
$\sigma(Sales)_{i,t}$	0.2084	0.2080	0.09
$Tangibility_{i,t}$	0.2538	0.2538	0.00
$OperCycle_{i,t}$	4.7537	4.7550	-0.08
$CFOSales_{i,t}$	-0.2120	-0.2187	0.00
$ZScore_{i,t}$	1.0547	1.0547	0.00
$LogAge_{i,t}$	20.6201	19.1562	1.30

Panel B Propensity score matching panel OLS

	Dependent variable: $INV\_INEFF_{i,t+1}$			Dependent variable:	
Independent variables	Entire sample	Over-investment sample	Under-investment sample	$Capex\_INEFF_{i,t}$	$NonCapex\_INEFF_{i,t}$
$\boldsymbol{LnOptVol_{i,t}}$	**-0.7151*** **	**-0.2080**	**-0.8108*** **	**-0.1651**	**-0.5268** **
	(0.2737)	**(0.3853)**	**(0.2261)**	**(0.1422)**	**(0.2436)**
Controls	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES
N	25,670	8,374	17,138	25,670	25,670
R-square	0.0655	0.0895	0.1131	0.1214	0.0426

Note: Panel A reports average treatment effects obtained from propensity score matching (PSM -Section 4.3), between firms with high options trading activity (above FF48 sector-year median), representing our treatment firms, and firms with low options trading activity, or our control firms. Panel B of the Table reports the results of the PSM estimation of equation (4) that is shown in the main text. The second column reports results for the entire sample, while the third (respectively fourth) column reports results for the over-investment (respectively under-investment) subsample, $INV\_INEFF_{i,t+1} \geq 0$ (respectively $INV\_INEFF_{i,t+1} < 0$). The fifth (respectively sixth) column reports results for $Capex\_INEFF_{i,t}$ (respectively $NonCapex\_INEFF_{i,t}$) as the dependent variable. The sample selection process is described in Section 3.1 All variables are defined in Appendix A. Standard errors double-clustered at the firm and the industry level (FF48 sectors) are reported in parentheses. ***, ** and * indicate statistical significance at 1%, 5% and 10% respectively.

Table 6 Effect of options volume on investment efficiency, external monitoring channel

	Dependent variable: $INV\_INEFF_{i,t+1}$		
Independent variables	(1)	(2a) Firms with credit rating	(2b) Firms without credit rating
$\boldsymbol{LnOptVol_{i,t}}$	**-1.0438*** **	**-0.5519**	**-1.1360*** **
	(0.2812)	**(0.3425)**	**(0.3521)**
$\boldsymbol{InstitOwn.-top\ five\_H-L_{i,t}}$	**-1.0810*** **		
	(0.3062)		
$\boldsymbol{LnVol_{i,t} \times InstitOwn.-top\ five\_H-L_{i,t}}$	**0.9092***		
	(0.5075)		
$Lev_{i,t}$	-4.1806***	-6.2912***	-6.5775***
	(0.6738)	(1.0891)	(0.8737)
$LogTA_{i,t}$	-0.5864***	-1.5765***	-0.1940
	(0.1224)	(0.1936)	(0.1481)
$MB_{i,t}$	1.0883***	0.6941***	1.1973***
	(0.1413)	(0.2611)	(0.1537)
$\sigma(I)_{i,t}$	1.1350***	0.5723	1.1845**
	(0.4266)	(0.8061)	(0.4917)
$\sigma(CFO)_{i,t}$	3.5961	20.6012***	0.9020
	(2.9195)	(6.4012)	(3.1621)
$\sigma(Sales)_{i,t}$	2.0469***	-0.1423	2.6712***
	(0.7076)	(1.0197)	(0.9159)
$Tangibility_{i,t}$	6.4903***	7.7176***	6.2652***
	(0.6009)	(0.8761)	(0.7687)
$OperCycle_{i,t}$	-0.4450***	0.1431	-0.6246***
	(0.1463)	(0.2497)	(0.1742)
$Loss_{i,t}$	-2.3427***	-2.3066***	-2.1651***
	(0.3217)	(0.4203)	(0.4467)
$CFOSales_{i,t}$	-0.0482	0.2234	-0.0474
	(0.0566)	(0.1560)	(0.0576)
$Dividend_{i,t}$	-0.2741	-0.5586	0.0133
	(0.3062)	(0.4640)	(0.3875)
$Slack_{i,t}$	-0.0042***	0.0605*	-0.0043***
	(0.0012)	(0.0336)	(0.0012)
$ZScore_{i,t}$	-1.0144***	0.0794	-1.3410***
	(0.2263)	(0.2231)	(0.2854)
$LogAge_{i,t}$	-0.0134*	-0.0061	-0.0339***
	(0.0073)	(0.0087)	(0.0120)
Intercept	1.2370	4.2292*	0.4995
	(1.4878)	(2.3790)	(1.7914)
Year FE	YES	YES	YES
N	34,090	13,943	20,147
R-square	0.0630	0.0651	0.0782
No of firms	4,860	1,937	4,026

Note: This table reports OLS estimation results of equation (4) that is shown in the main text, when interacting our independent variable of interest $LnVol_{i,t}$ with an indicator variable of institutional blockholder ownership, and when estimating this equation for firms with and without a credit rating for their long-term debt separately. The sample selection process is described in Section 3.1. All variables are defined in Appendix A. Standard errors double-clustered at the firm and the industry level (FF48 sectors) are reported in parentheses. ***, ** and * indicate statistical significance at 1%, 5% and 10% respectively.

Table 7 Effect of options volume on investment efficiency, supplementary analysis

	Dependent variable: $INV\_INEFF_{i,t+1}$							
Independent variables	(1a) Unexpected investment above median	(1b) Unexpected investment below median	(2a) Business segments above median	(2b) Business segments below median	(3a) Geographical segments above median	(3b) Geographical segments above median	(4a) Firms with CDS trading	(4b) Firms without CDS trading
$\boldsymbol{LnOptVol_{i,t}}$	**-0.5787****	**-0.4335**	**-0.3341**	**-1.2670*****	**-0.1592**	**-0.8381****	**-0.0316**	**-1.2163*****
	(0.2639)	**(0.3213)**	**(0.3294)**	**(0.3998)**	**(0.3960)**	**(0.3575)**	**(0.4970)**	**(0.3444)**
$Lev_{i,t}$	-7.5815***	-0.2256	-2.3720***	-9.1025***	-2.8269***	-5.8604***	-0.4835	-5.4252***
	(0.7490)	(0.7264)	(0.8359)	(1.0745)	(1.0412)	(0.9340)	(1.9075)	(0.7109)
$LogTA_{i,t}$	-0.5482***	-0.5742***	-0.7597***	-0.3684*	-1.0938***	-0.1763	-1.3858***	-0.3748***
	(0.1110)	(0.1398)	(0.1427)	(0.1906)	(0.1782)	(0.1605)	(0.3752)	(0.1248)
$MB_{i,t}$	1.6598***	0.4258***	0.7607***	1.3568***	0.9021***	1.3920***	0.3978	1.1972***
	(0.1685)	(0.1184)	(0.1986)	(0.1680)	(0.1640)	(0.2194)	(0.2926)	(0.1475)
$\sigma(I)_{i,t}$	1.1232**	0.7864	0.7683	1.3340**	1.1953*	0.3236	-1.6344	1.2643***
	(0.5212)	(0.5104)	(0.7027)	(0.5630)	(0.6649)	(0.4742)	(2.0977)	(0.4367)
$\sigma(CFO)_{i,t}$	5.1288	-4.7628*	13.5215***	-1.5562	10.2191**	1.1695	12.3626	2.7695
	(3.4929)	(2.7620)	(4.8340)	(3.4926)	(5.1475)	(3.8836)	(10.2384)	(2.9935)
$\sigma(Sales)_{i,t}$	2.1090***	0.6529	0.2160	2.8146***	0.1795	2.4584***	-0.7791	2.2639***
	(0.7954)	(0.7791)	(0.8599)	(1.0467)	(1.0764)	(0.9126)	(1.8788)	(0.7601)
$Tangibility_{i,t}$	6.3658***	4.2473***	5.3777***	9.7352***	4.0610***	8.4923***	6.9046***	6.7433***
	(0.6617)	(0.6877)	(0.7574)	(0.9275)	(0.9587)	(0.8610)	(1.3514)	(0.6718)
$OperCycle_{i,t}$	-0.3554**	-0.8935***	-0.6022**	-1.7511***	-1.6846***	-0.9036***	-0.2504	-0.4637***
	(0.1423)	(0.2128)	(0.2571)	(0.2506)	(0.3702)	(0.2554)	(0.4331)	(0.1564)
$Loss_{i,t}$	-1.6267***	-2.6851***	-3.1300***	-1.0876*	-1.7650***	-2.3944***	-1.7920***	-2.5060***
	(0.4223)	(0.3031)	(0.3300)	(0.5648)	(0.4121)	(0.4562)	(0.6212)	(0.3549)
$CFOSales_{i,t}$	-0.0824	-0.0043	-0.0895	-0.0613	-0.0365	-0.1254	1.5365	-0.0454
	(0.0674)	(0.0281)	(0.1315)	(0.0593)	(0.0883)	(0.1041)	(2.2189)	(0.0566)
$Dividend_{i,t}$	-0.7204**	0.4453	-0.2424	-0.8159*	-0.2926	-0.5816	-0.3191	-0.2827
	(0.3364)	(0.3594)	(0.3957)	(0.4658)	(0.4564)	(0.4260)	(0.8085)	(0.3284)

$Slack_{i,t}$	-0.0012	-0.0049***	-0.0033***	-0.0046***	-0.0038***	-0.0045**	0.0977***	-0.0042***
	(0.0014)	(0.0006)	(0.0009)	(0.0015)	(0.0005)	(0.0018)	(0.0366)	(0.0012)
$ZScore_{i,t}$	-1.5947***	0.0959	-0.3134	-1.1173***	-0.5807*	-0.9402***	0.7551	-1.1239***
	(0.2687)	(0.1368)	(0.2501)	(0.3119)	(0.3079)	(0.2487)	(0.5085)	(0.2415)
$LogAge_{i,t}$	-0.0117	0.0026	-0.0001	-0.0462***	-0.0069	-0.0070	-0.0171	-0.0190*
	(0.0071)	(0.0089)	(0.0081)	(0.0155)	(0.0110)	(0.0100)	(0.0129)	(0.0100)
Intercept	4.3700***	-1.7736	0.6394	6.0975***	10.1496***	-0.4640	4.0036	-0.1843
	(1.6752)	(1.6994)	(2.0702)	(2.1736)	(2.6682)	(2.1223)	(4.4122)	(1.5303)
Year FE	YES	YES	YES	YES	YES	YES	YES	YES
N	17,684	15,889	19,403	13,784	15,165	13,400	5,551	28,539
R-square	0.1275	0.0340	0.0436	0.1015	0.0622	0.0690	0.0620	0.0638
No of firms	3,911	3,530	2,846	2,843	2,194	2,611	403	4,457

Note: This table reports OLS estimation results of equation (4) that is shown in the main text. The sample selection process is described in Section 3.1. Equation (4) is estimated separately for firm-year observations with unexpected investment, and number of business and geographical segments above or below the sample-year median, and also for firms with and without CDS trading. All variables are defined in Appendix A. Standard errors double-clustered at the firm and the industry level (FF48 sectors) are reported in parentheses. ***, ** and * indicate statistical significance at 1%, 5% and 10% respectively.

Table 8 Effect of options volume on investment efficiency, robustness controls

	Dependent variable: $INV\_INEFF_{i,t+1}$			
Independent variables	(1)	(2)	(3)	(4)
$\boldsymbol{LnOptNon\$Vol_{i,t}}$	**-0.1165***			
	(0.0612)			
$\boldsymbol{LnVolCalls_{i,t}}$		**-1.0590*****		
		(0.3339)		
$\boldsymbol{LnVolPuts_{i,t}}$			**-1.0576*****	
			(0.3718)	
$\boldsymbol{LnOptVolDelta_{i,t}}$				**-0.1138****
				(0.0498)
$Lev_{i,t}$	-4.2234***	-4.5517***	-4.3524***	-4.2820***
	(0.6662)	(0.6659)	(0.6667)	(0.7157)
$LogTA_{i,t}$	-0.5602***	-0.4698***	-0.5343***	-0.6430***
	(0.1165)	(0.1129)	(0.1100)	(0.1169)
$MB_{i,t}$	1.1199***	1.1504***	1.1204***	1.1331***
	(0.1363)	(0.1375)	(0.1349)	(0.1404)
$\sigma(I)_{i,t}$	1.1589***	1.1703***	1.0986***	1.0915**
	(0.4280)	(0.4279)	(0.4203)	(0.4353)
$\sigma(CFO)_{i,t}$	3.2871	3.4781	3.8520	2.6865
	(2.9211)	(2.9146)	(2.9096)	(3.0497)
$\sigma(Sales)_{i,t}$	1.9897***	2.0610***	1.7561**	2.0328***
	(0.7099)	(0.7085)	(0.6978)	(0.7548)
$Tangibility_{i,t}$	6.5862***	6.6213***	6.6356***	6.7313***
	(0.6019)	(0.6015)	(0.6009)	(0.6389)
$OperCycle_{i,t}$	-0.4542***	-0.4547***	-0.4353***	-0.5488***
	(0.1468)	(0.1465)	(0.1469)	(0.1567)
$Loss_{i,t}$	-2.5139***	-2.4777***	-2.4091***	-2.5385***
	(0.3240)	(0.3229)	(0.3217)	(0.3554)
$CFOSales_{i,t}$	-0.0504	-0.0491	-0.0450	-0.0532
	(0.0566)	(0.0566)	(0.0572)	(0.0588)
$Dividend_{i,t}$	-0.1569	-0.1960	-0.1959	0.0056
	(0.3075)	(0.3063)	(0.3056)	(0.3269)
$Slack_{i,t}$	-0.0042***	-0.0042***	-0.0042***	-0.0045***
	(0.0012)	(0.0012)	(0.0012)	(0.0012)
$ZScore_{i,t}$	-1.0156***	-1.0197***	-0.9565***	-1.0227***
	(0.2265)	(0.2271)	(0.2268)	(0.2435)
$LogAge_{i,t}$	-0.0148**	-0.0133*	-0.0141*	-0.0158**
	(0.0075)	(0.0073)	(0.0074)	(0.0078)
Intercept	1.5946	-0.0961	0.1976	2.3066
	(1.3596)	(1.3967)	(1.3954)	(1.4375)
Year FE	YES	YES	YES	YES
N	34,090	34,021	33,865	29,735
R-square	0.0616	0.0622	0.0611	0.0643
No of firms	4,860	4,855	4,836	4,760

Note: This table reports OLS estimation results for several different robustness checks. In specification (1), the non-dollar options volume is used as the independent variable of interest. In specifications (2) and (3), the dollar options volume for call options and put options are employed, respectively. Specification (4) uses the natural logarithm of the absolute delta-weighted option volume (based on Lakonishok et al., 2007, and Cao et al., 2020a) as an independent variable. The sample selection process is described in Section 3.1. All variables are defined in Appendix A. Standard errors double-clustered at the firm and the industry level (FF48 sectors) are reported in parentheses. ***, ** and * indicate statistical significance at 1%, 5% and 10% respectively.