Buybacks Behaviour and the Anti-Dilution of Dilutive Stock Options

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Abstract

We study how dilutive board-level stock options impact anti-dilutive daily buybacks in the UK. We show that buyback behaviour and stock option holdings positively influence cumulative post-buyback returns. Buybacks, however, have anti-dilutive implications and are thus linked to the level and nature of dilutive stock options outstanding. We find increases in aggregate stock options to escalate buyback implementation. This is driven largely by unvested stock options that significantly enhance anti-dilutive benefits. Robustness tests using "overconfident" board classification and treasury share regulation confirm the anti-dilutive motive behind buybacks when stock options are unvested.

Keywords: Stock options, buyback, dilution, overconfidence, treasury shares
JEL Classification: G30, G35, J33

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1 Introduction

If a company gives out a stash of options diluting shareholders by 10 per cent and then buys them all back, you could say nobody got harmed. But the truth is that the money does not find its way back to shareholders but into the pockets of employees as a substitute for wages that would otherwise need to be expensed.

— Bolko Hohaus*, Lombard Odier (Financial Times, May 8, 2015)*

What is the significance of stock option grants in stimulating daily repurchase activity? While Mr. Hohaus is right in questioning the benefits of buyback in a world of dilutive stock options, his intentions do not consider the dynamics of either stock option grants or buyback behaviour. If firms motivate repurchase of shares to meet stock option exercise commitments, the importance of this question depends not just on the level and nature of option grants, but also on how buybacks are implemented. The aim of this paper is to address this question by observing daily buyback behaviour as an anti-dilutive tool that enables firms to fund dilutive stock options and achieve repurchase flexibility benefits to shareholders.

Studies that examine the effect of managerial stock options on a firm's repurchase decision show conflicting results. Kahle (2002) finds that although the levels of total and unvested executive stock options influence the initial decision to repurchase, actual buyback transactions are unaffected by either the aggregate or vesting conditions of executive grants. This is contradicted by Jolls (1998) and Weisbenner (2000) who find firm repurchases to be driven by executive stock option holdings and firm retained earnings. Similarly, Fenn and Liang (2001) show the levels of managerial stock options to significantly influence the shares repurchased by a firm. Although the latter study does not consider the vesting conditions of stock option grants, the differences in these findings highlight a gap in literature that we aim to fulfil using a granular level of buyback transaction data from the United Kingdom (UK).

In similar context, findings by Bens et al. (2003) suggest that firms repurchase shares to manage the dilution effect of stock options on indicators important to market participants. However, the net effect of dilution from stock options on accounting parameters, such as earnings per share (EPS), is difficult to assess when a firm has a simultaneous buyback program in place. The readjustment of a firm's dilution-inclusive financial leverage cannot be realised at the time of obtaining a buyback authority due to their non-committal nature. Our study is unique in incorporating the levels and vesting state of stock option holdings in a daily repurchase setting that enables and signifies the assessment of anti-dilutive benefits of buybacks.

The benefit of using the UK institutional setting is not limited to the use of daily firm share buyback data. The change in accounting treatment of firm share repurchases in the UK in December 2003 meant that while all repurchases had to previously be cancelled, publicly listed firms now had the recourse to hold repurchased shares in Treasury in order to meet future option exercise commitments.[1] This avoids the need for a firm to make secondary issues, which impose significant capital cost. The application of this regulation change in our study is, to our knowledge, the first to assess the anti-dilutive implications of share buybacks. The use of the Treasury regulation change, along with daily buyback implementation data, enables us to contribute significantly to the literature as the UK institutional setting not only enables us to assess the importance of buyback behaviour to shareholders, but also how option holdings at different vesting stages of their life influence the tendency of a firm to continuously repurchase shares.

In order to ascertain if share buybacks induce anti-dilutive benefits, we first need to establish if the variability in buyback implementation behaviour is perceived differently by shareholders. The multitude of buyback motives unearthed in prior literature suggests that firms place significant value on the flexibility of repurchases.[2] The value implication of this flexibility to shareholders however is debatable. Jagannathan and Stephens (2003) and Dittmar and Field (2015) examine the benefits of buyback flexibility using either the frequency of program announcement or actual monthly repurchases as proxy. Their findings suggest that buyback flexibility enabling lower frequency repurchases drive significantly positive long-term abnormal returns to shareholders, consistent with the earlier findings of Ikenberry et al. (1995). Such findings imply that managers are not only able to time the market by repurchasing infrequently, but doing so is beneficial to shareholders.

Using frequency of buybacks to establish strategic behaviour that might benefit shareholders could also imply private incentives for managers. Barclay and Smith (1988) show that informed managers have an incentive to manage a firm's repurchase policy, which can increase a firm's cost of capital. Similarly, Brockman et al. (2008) find that managers create incentive opportunities through buybacks by manipulating information flow and false signalling that is potentially misleading investors (Chan et al., 2010). Timing the market to hunt for bargain prices can lead to incomplete buyback programs, thus exposing a firm to high agency costs (Ikenberry and Vermaelen, 1996). More recent evidence by Bonaimé et al. (2016) suggests that managers are poor market timers, leading to higher repurchasing cost for a firm. Such strategic buybacks can have a negative impact on firm investments and employment (Almeida et al., 2016). These arguments suggest a disagreement on how flexibility in buyback impacts shareholders and managers.

Using a unique dataset of daily share buybacks by UK firms from 1999 to 2010, we aim to

[1]The Company's Act (1985), since superseded by the Company's Act (2006), introduced the Companies (Acquisition of Own Shares) (Treasury Shares) Regulations 2003 (SI 2003/1116) (the Regulations) amendment to enable companies to hold up to 10 percent of their issued shares in Treasury. Listing Rule 12.6 detail the exchange rules pertaining to dealing in Treasury shares.

[2]See Brav et al. (2005) and Dittmar (2000) for a comprehensive analysis of various buyback motives. Also see Allen and Michaely (2003) and Farre-Mensa et al. (2014) for a survey of payout policy literature.

resolve this difference by adopting an event study methodology to determine the importance of differential buyback behaviour to shareholders. Our univariate results point to significantly lower returns prior to repurchases, which is temporarily reversed on buyback days but continues to drift lower for up to two days post-repurchase. This return behaviour is however dependent on the consecutive implementation of buybacks. Pre-buyback cumulative returns are consistently negative while the event day returns significantly positive in a three-day window only for buybacks implemented serially longer. Cross-sectional analyses controlling for various firm-level factors confirm the differences between buyback behaviour on consecutive implementation, showing higher post-repurchase returns for up to three days if buybacks are serially implemented. Dilutive stock options also increase the significance of returns around buyback events, with the post-buyback returns lower for increasing levels of vested grants.

The anti-dilutive setting of buybacks is appealing due to the offsetting nature of payout flexibility on option-funding cost. Stephens and Weisbach (1998) suggest that buyback policy has a cost-saving objective as repurchased shares can be held in Treasury to meet future stock option exercises by employees. Survey evidence by Brav et al. (2005) confirms that part of the repurchase objective is to offset stock option dilution. Our paper argues that the anti-dilutive benefit of repurchases is dependent on the vesting schedule of stock option grants. Once vested, risk-averse managers are likely to exercise their stock options that are in-the-money. In order to offset dilution of existing shareholders and lower option funding cost, the flexibility of a buyback authority is restricted by the vesting conditions of stock option plans. Repurchasing when options vest exhausts the benefits of flexibility for shareholders as repurchases are likely to be driven by the stock option exercise demands of the manager. This lowers the mitigating effect of repurchase flexibility on dilutive stock option grants, thereby increasing the option-funding cost. However, buyback flexibility has value implication to shareholders before options vest, leading to anti-dilutive benefits of repurchases. Using data on executive stock option vesting dates, we assess the anti-dilutive implications of buybacks under varying vesting conditions of option grants.

In order make our anti-dilution intuition more tangible, we employ two treatment effects individually as robustness. The study of managerial overconfidence by Malmendier and Tate (2005, 2008) indicates that managers often overestimate returns from investments and mergers. In the anti-dilution context, overconfident managers would try to time their buybacks and delay transactions to closer to their intended option vesting. These actions by overconfident boards would confirm the anti-dilutive implications of share buybacks. Additionally, we also observe the change in Treasury regulation that determine the extent of anti-dilution effect of buybacks. If the change in regulation enabled firms to hold shares in Treasury that minimised capital cost, we should observe increased buyback behaviour post-regulation for firms with higher unvested option grants. Consequently, we should also observe reduced buybacks when options are vested, marking a shift in buyback behaviour around regulation change.

Using a hazard model that focuses on the drivers of repeated repurchase transaction, we examine if dilutive stock options drive the difference in repurchase behaviour. At the baseline level, our specification suggests an increasing hazard-rate of buybacks for firms with options outstanding, with the rate greater for unvested options. Anti-dilutive benefits of repurchases are apparent for unvested grants when buybacks are implemented repeatedly, while vested grants generate relatively reduced payout behaviour. We test the robustness of this finding by using managerial overconfidence and change in Treasury regulation as treatment variables. Our findings show that the hazard rate for dilutive options on repurchases is significantly lower for boards classified as overconfident relative to others. This is more prominent if overconfident boards hold large vested options. The change in Treasury regulation, which provides firms with opportunities to lower their option-funding costs, suggests that the hazard-rate of unvested options on buyback persistence increased after 2003, while reducing for options that are vested. These findings suggest that the anti-dilutive effect of repurchases is conditional on the vesting condition of stock options, which determine the balance between benefits of buyback flexibility and costs associated with meeting stock option exercises.

Our analysis in this paper extends the existing evidence we have on the anti-dilutive benefits of repurchases. Prior research by Weisbenner (2000), Fenn and Liang (2001), Kahle (2002) and Bens et al. (2003) have implied capital cost savings by holding repurchased shares in Treasury. However, the implicit relation has not been empirically tested. Our results adds to the increasing implication of overconfident managers on firm payout policy (Banerjee et al., 2015). Our study also uses a regulatory change event in the sample period that addresses the anti-dilutive benefits of buybacks, which we find to be greater when stock options are unvested. This analysis, and its further implication to shareholders greatly benefits from data on daily repurchase disclosure in the UK, which has not been sufficiently explored before.

The rest of the paper is organised as follows: the next section discusses the motivation and the hypotheses tested; Section 3 introduces the sample data, distribution of daily repurchases and preliminary statistics on the data used in this study; Section 4 presents the empirical results and their implications; Section 5 concludes.

2 Motivation and hypotheses

Within corporate payout policy, share repurchase has become more prominent than dividend payments (Skinner, 2008). While early research has developed theories to help understand the importance of repurchases, much of the corresponding empirical evidence relates to a firm's announcement of intention to repurchase. Share buybacks grew in popularity due to their ability to provide flexibility for firms to engage the market without any commitment. This flexibility in buybacks without obligation limits a firm's ability to consistently target a single objective over the long validity of a program. In line with the flexibility arguments of Stephens and Weisbach (1998), Jagannathan et al. (2000), Guay and Harford (2000) and Ikenberry et al. (1995), it would be difficult to judge the true intention of a repurchase at the time of the announcement.

Literature has recently started to make use of detailed information in actual share buybacks by firms, putting focus on the duration and intensity of the transactions. Ginglinger and Hamon (2007) and Brockman and Chung (2001) study the impact on liquidity and market timing by firms using daily buybacks data from France and Hong Kong, respectively. Recent study by Ben-Rephael et al. (2014) takes advantage of the newly available information in the US to study the implications of repurchase actions at a monthly level due to inaccuracies in estimating repurchases (Banyi et al., 2008).[3] Using similar monthly-level data, Dittmar and Field (2015) suggest a difference in buyback behaviour that yields significant abnormal returns for infrequent repurchasers. Using the frequency of program announcements in the US, Jagannathan and Stephens (2003) show similar findings.

The significance of share buybacks is reflected in the flexibility with which firms implement it. Buyback programs, when announced, are typically very large with broad motives aimed at being fulfilled over the long-term. In a survey of executives by Brav et al. (2005), one of the most commonly cited motive behind buybacks is the ability of firms to cover option exercises. By repurchasing shares, the firm avoids the need to issue new equity when firm employees exercise their option grants that vest and are in-the-money. This motive is also seen as the primary reason for the growth in share buybacks as a popular payout tool (Kahle, 2002). Buybacks thus provide firms with the flexibility to meet their payout and compensation commitments at any point of the vesting schedule of option grants, if buybacks are motivated by stock dilution.

The concurrent presence of flexible buyback plans and dilutive stock options also means that firms effectively hold two implicit options. As buyback programs provide the flexibility for firms to repurchase without any commitment, this payout behaviour is synonymous with holding an exchange option. Ikenberry and Vermaelen (1996) show that buybacks as exchange options are exercised by firms when they find themselves undervalued, thereby exchanging the lower market value with a far higher true firm value. If they are announced in advance to expected implementation, these exchange options have implied value to a firm that helps avoid signalling cost. Additionally, granting stock options to employees with pre-determined vesting schedules means that firms hold a short position on call option on their stock. Firms have to fulfil the incentive commitments to employees when the latter decide to exercise their stock options.

The simultaneous presence of an exchange option through buyback and a short-call on

[3]Exchange Act Rule 10b-18 came in to effect on March 15, 2004.

stock options suggests that implementation through buybacks should aim to mitigate the risk of the latter. The flexibility objective behind buybacks then translates in to maximising the benefit of the exchange option over the short-call position on stock options granted. The implication of this is that firms should repurchase shares to minimise the dilutive effect of stock options while the latter are unvested. Risk-averse managers will look to exercise once their vested stock options end up in-the-money. Without any Treasury shares, a firm's buyback behaviour will then be conditional on a manager's exercise behaviour. This would imply that the exchange option benefit of repurchases is reduced while the cost associated with a short-call on stock options increases. This mimics the intuition of Babenko (2009) who proposes that the likelihood of program announcement is higher for firms that have large quantities of unvested options. Hence, we declare our baseline hypothesis, in alternative form, as follows:

H1a. Dilutive stock options increase the continuity of anti-dilutive buybacks.

H1b. Relative to vested stock options, dilutive unvested stock options increase the continuity of anti-dilutive buybacks.

The above hypotheses, similar to the option-funding hypothesis of Kahle (2002), help us establish a link between dilutive stock options and buyback continuity, defined as the number of consecutive buyback days. However, in order to understand if managerial strategic behaviour guides the continuity in firm repurchases, we utilise a treatment variable that distinguishes boards who are more likely to act strategically in their investment and financing decisions from non-strategic boards. Malmendier and Tate (2005, 2008) study the impact of overconfident boards on investment decisions and find them serially overestimating the returns on investments and merger benefits. In a similar context, survey evidence by Brav et al. (2005) shows that managers are confident of their ability to time the market with respect to share repurchases. If confidence is a key trait in a manager's ability to time the market and is consequently costly to shareholders, we should expect overconfident boards with dilutive stock options to be less driven to buyback shares relative to boards not classified as overconfident.

Additionally, as flexibility is a key ingredient in share buybacks, overconfident boards are likely to overestimate the benefit of this flexibility by delaying the repurchase decision. In our case, this would mean that overconfident boards are more likely to time the buyback of shares closer to their intended stock option exercise than when stock options are unvested. Hence, relative to non-overconfident boards, we should expect overconfident boards to repurchase shares less continuously when they hold large proportions of vested stock options. Overconfident boards are likely to continue to be strategic in their buybacks even when they hold large proportions of unvested option grants. However, taking into consideration the risk-averse nature of managers, overconfident boards certain of their intention to exercise once their own stock options vest could increase buyback transactions right before vesting. Hence, the relationship between overconfident boards and unvested options is difficult to establish. Therefore, we capture the private benefits to overconfident boards through buyback continuity using our second hypothesis, stated in alternative form as follows:

H2a. Relative to non-overconfident boards, overconfident boards with dilutive stock options reduce the continuity of anti-dilutive buybacks.

H2b. Relative to non-overconfident boards, overconfident boards with dilutive vested stock options reduce the continuity of anti-dilutive buybacks.

An additional resource that can help establish if repurchases are driven by shareholder benefit or managerial opportunism is the use of an event that is exogenous to the continuity parameter. Prior to December 1, 2013, all shares repurchased by UK listed companies had to be cancelled immediately. This meant that any exercise of stock options had to be met by a secondary issue. After the change in regulation, firms were allowed to hold repurchased shares in a Treasury and thus avoid costs related to secondary issue of shares. This would mean that firms driven to maximise the flexibility benefit for shareholders would increase their buyback continuity after the change in regulation. Alternatively, prior to the change in regulation, if firms were already anti-dilutive with their buyback behaviour the average effect of dilutive stock options on buyback continuity should not change. Hence, the aggregate effect of dilutive stock options on anti-dilutive repurchases is indeterminate around change in regulation.

Contrary to the effect of aggregate level of stock options, regulation change implies a clear benefit if firms hold unvested stock options. This event signified the cost saving of a buyback, which as per our earlier intuition (H1b) should induce firms to repurchase shares when stock options are unvested. Post-introduction of regulation concerning Treasury shares, repurchasing shares when stock options have vested would provide significantly lower flexibility benefit of the implied exchange option and higher cost with respect to the short-call option on the stock. Hence, we state our third and final hypothesis, in alternate form, as follows:

H3. Relative to vested stock options, dilutive unvested stock options increase the continuity of anti-dilutive buybacks after the change in Treasury regulation more than prior to regulation change.

The hypotheses highlighted above help determine not just if stock option holdings drive anti-dilutive buyback behaviour, but also contextualise the same relationship when overconfident board members are strategic. Using the change in regulation as an exogenous shock, we determine the extent to which dilutive stock options can influence anti-dilutive buyback behaviour.

3 Data and methodology

3.1 Sample construction

We utilise the UK regulatory framework which requires firms to disclose their repurchase volume and prices within one trading day of transaction date.[4] Data on daily buyback implementations however are not readily available from secondary sources. Hence, we gather a list of UK firms that sought buyback authorities using the Securities Data Company (SDC) database. Our aim was to find firms that only obtained authority to repurchase in the open-market, and not tender-offers or dutch auctions. We identify 196 firms that obtained open-market buyback authorities and, using Perfect Information (PI), we expand the identification to 2,762 firm years and 10,623 daily repurchase transactions during the period of 1990 to 2010. As the implementation of an open-market program is non-obligatory, daily repurchase transactions pertain to 159 firms in the sample.

The anti-dilution channel of repurchases is used to help explore the drivers of buyback behaviour. Hence, we resort to the detailed information on board characteristics and compensation provided by BoardEx. BoardEx provides information on the number, strike price and vesting date of stock options for each firm, by executive-option plan. We aggregate the data for all managers, executive and non-executive, by firm-plan that is available for all years that the plan is active or has options outstanding.[5] We merge all available information on stock options with the hand-collected repurchase data. As the BoardEx sample begins in 1999, we loose all information prior to this period. The merged dataset represents 9,129 repurchase days over the final sample period between 1999 and 2010. These buybacks correspond to 80 firms while 39 additional firms obtain repurchase authorities which they do not implement. A description on how this sample was compiled is provided in Table 1.

[TABLE 1 GOES HERE]

3.2 Methodology

In order to establish if dilution-inclusive stock options influence the continuity or frequency of share buybacks, we need to first determine if repurchase behaviour varies and leads to different anti-dilutive effects. To aid this process, we employ our sample described in Table 1 in event study form to illustrate univariate effects of share repurchases on firm stock returns, and cross-sectional differences in different buyback behaviour. We then examine the daily transaction

[4]FSA Listing Rule 12.4.6 states that 'any purchase of a listed company's own equity shares by or on behalf of the company or any other member of its group must be notified to a Regulatory Information Service (RIS) as soon as possible, and in any event by no later than 7:30 a.m. on the business day following the calendar day on which the purchase occurred.'

[5]Hence, if an option plan falls out of the dataset without expiring, we assume the plan to be exercised or cancelled.

data as a dependent variable in a survival model that determines the instantaneous tendency of a firm to repurchase shares repeatedly, conditional on firm-specific heterogeneity. We describe the methodologies below.

3.2.1 Buyback behaviour

Our initial analysis focuses on the univariate and multivariate significance of returns on and around repurchase days in the UK. To achieve this, we utilise a maximum likelihood non-linear model, as proposed by Prabhala (1997) that helps deal with potential misspecification in the context of expectations of repurchase events.[6]

Similar to Jun et al. (2009), we employ an event window of -5 to +5 around each event day, which makes our study comparable to others in the literature. As the institutional environment in the UK enables firms to disclose their daily buybacks by market open of the day following the buyback, we consider both the implementation and the day after as event days.[7] Typical event studies use an OLS market model that estimates returns based on predictions within an estimation window, adjusted for market returns. As repurchase events are sporadic and are likely to affect the momentum of returns in the estimation window, we make use of the four-factor model proposed by Carhart (1997) that includes a momentum parameter, in addition to market, size and value adjustments. We make use of data on daily four-factor estimated for UK companies and provided by Gregory et al. (2013). In implementing this methodology, we define our estimation window as a six month period prior to each event window. During the days of -131 to -6, we estimate the following model for each firm over the time series of the sample.

$$\begin{aligned} Return_t &= \alpha + \beta_1 Market_t + \beta_2 SmallMinusBig_t \\ &+ \beta_3 HighMinusLow_t + \beta_4 Momentum_t + \epsilon_t \end{aligned} \quad (1)$$

Commonly used in asset pricing literature, eq. (1) above uses the Carhart four-factors in return estimation while also being analogous to the conventional market model commonly used in payout research (Ikenberry et al., 1995). Returns are predicted in the estimation window based on a linear regression of market, size, value and momentum factors. The predicted values from this specification are used then to estimate, for each repurchase cluster in the sample event window, the average abnormal returns (AAR) as the difference between actual

[6] In untabulated results, we also implement the conventional OLS model commonly used in event studies (Brown and Warner, 1985), modified to incorporate repurchases undertaken prior to event in question. Results here are largely similar, but with weaker statistical power.

[7] This would imply that in the event window, +1 to +5 event days are effectively +2 to +6 trading days from implementation.

returns observed and predicted by the model, i.e. ϵ_t. Similarly, we compute cumulative average abnormal returns ($CAAR$) over multiple groupings of days in the event window.

To further validate the importance of the observed abnormal returns around repurchase days, we utilise a multivariate framework in a cross-sectional setting to determine the impact of buyback continuity. We use the following specification to help draw a relationship.

$$\begin{aligned} CAAR_i &= \beta_1 Continuity_i + \beta_2 \Delta Options_i + \beta_3 Size_i + \beta_4 InvestmentOppurtunity_i \\ &+ \beta_5 Volatility_i + \beta_6 Spread_i + \beta_7 LaggedReturns_i + \beta_8 DividendPayout_i + \epsilon_i \end{aligned} \quad (2)$$

In eq. (2) above, we regress different cumulative return variables ($CAAR$) estimated based on the Carhart four-factor model, individually, on a buyback continuity parameter (*Continuity*). This variable is observed, separately, either as a dummy or a continuous variable. The dummy determinant takes a value of unity if repurchases are undertaken for only one trading day, and zero if repurchases are consecutively done for two or more days. The continuous parameter captures the total number of repurchase days in an event (scaled by number of trading days in that year). Another important variable included in the specification above is the change in option holdings parameters (Δ*Options*) that helps capture the effect of a change in the variable (including the segregations of vested and unvested grants) on post-buyback returns. We control for other parameters used commonly in the literature that show cross-sectional variability in a daily setting. We adjust for firm size (proxied by log-normalised market value), investment opportunity (proxied by market-to-book value), trading cost (volatility and spread), past stock performance and the dividend payout ratio. Definitions of how each of these variables are computed is provided in the Appendix. As our sample firms are less than the number of repurchase events, many events are bound to cluster by firms. Hence, we report cluster robust statistics in our findings.

3.2.2 Buyback continuity and dilutive stock options

The analysis above addresses if variability in buyback behaviour exists and the consequential effect of such repurchases on cumulative returns. The statistical and economic significance of this effect would suggest that investors benefit either when repurchases are infrequent (strategic) or frequent (continuous). To further examine the implication of continuity in repurchases, we examine if buybacks fulfil their anti-dilutive objective for stock options that are dilutive to existing shareholders.

The examination of buyback continuity involves the application of a likelihood function that determines the probability of a repurchase event occurring. However, daily repurchase events are constrained by exchange rules limiting the price at which buybacks can be undertaken and the proportion of volume that can be repurchased. Hence, there is likely to be significant autocorrelation in the implementation of buybacks. To account for this, we use a survival model that considers the likelihood of repeated repurchase implementation, with the probability of latter buybacks conditional on prior repurchases. Without resorting to a predetermined probability function, we first use a semi-parametric Cox proportional hazard model, described below.

$$\begin{aligned} h_{ik}(t|\theta_i) &= \theta_i h_0(t) exp(\beta \mathbf{X}_{ik}) \\ \text{where,} & \\ \mathbf{X} &= f(Options, Size, InvestmentOpportunity, \\ &\quad Volatility, Spread, LaggedReturns, DividendPayout) \end{aligned} \tag{3}$$

In the specification above, subscript i is a firm-specific parameter, while subscript k relates to number of repurchase intervals per firm in the sample. The hazard function is also conditional on a *frailty* parameter θ that captures firm-specific random effects. The vector $\mathbf{X}$ corresponds to all explanatory variables used in the hazard model. As our data captures 9,129 buyback days for 119 sample firms, we use daily-level firm control variables to capture the heterogeneity in firm characteristics. Variables used include options holdings, firm size, market-to-book, return volatility, average spread, past stock returns and dividend payout ratio.[8] As is standard in semi-parametric Cox models, the baseline hazard is undefined.

Ikenberry and Vermaelen (1996) show that firms avoid signalling costs by announcing a repurchase program early. The implication of this intuition is that as the likelihood of a buyback increases with time, the hazard model can be more structured in a parametric setting where we define the probability density function. This increasing hazard function can be defined using a Weibull distribution and an increasing shape parameter would be most appropriate. Therefore, we use the parametric model defined below.

$$\begin{aligned} h_{ik}(t|\theta_i) &= \theta_i \lambda p t^{p-1} \\ \text{where,} & \\ \lambda &= exp(\beta \mathbf{X}_{ik}) \\ \mathbf{X} &= f(HOL67, LONGHOL, TREASURY, Options, Size, InvestmentOpportunity, \\ &\quad Volatility, Spread, LaggedReturns, DividendPayout) \end{aligned} \tag{4}$$

[8] See Appendix for descriptions of variables used.

The specification is very similar to eq. (3), except for the predetermined probability function (λ) and its shape parameter (p), which we expect to be upward sloping. *Frailty* is again captured by θ. In addition, we also include the dummies of *HOL67*, *LONGHOL* and *TREASURY* that we use independently as a robustness for our anti-dilution argument. We motivate the use of each of these dummies below. The control variables are similar to the earlier specification, with option holdings being our primary variable of interest. In all specifications, the options holdings variable is also split into vested and unvested options to determine their individual dilution effects. The regression specification uses 9,129 repurchase days and another 119 observations (one for each sample firm) that adjusts for right-censoring when the sample period ends in 2010. Due to the nature of early buyback program announcements, we largely employ the parametric specification in our study.

3.2.3 Board overconfidence and buyback continuity

The baseline hazard regressions emphasise the effect of dilutive stock options on the persistence of buybacks, conditional on frailty. If strategic managerial behaviour guides the difference in buyback behaviour, we should also observe a difference in how such repurchases anti-dilute a firm's outstanding stock options. To examine this, we use board overconfidence as a treatment variable that distinguishes strategic from non-strategic boards. As defined earlier, Malmendier and Tate (2005, 2008) find overconfident boards more prone to overvaluing benefits from investments and mergers. Likewise, our hypothesis suggested overconfident boards to dilute less as they are more inclined to try time the market.

We examine the consequence of board overconfidence by using the definition of managerial overconfidence as per Malmendier and Tate (2005, 2008). As we incorporate stock option holdings at the board level (executive and non-executive members), we use the overconfidence parameter at the board level. We use two variables, individually, in relation to exercise behaviour after stock option vesting and when stock options are near expiry. The first variable, *HOL67* determines if boards, on aggregate, hold on to their vested options that are less than five years to expiry and are more than 67 percent in-the-money.[9] A board is classified as overconfident if it is found to breach these limits more than three times in the sample period.

The second variable, *LONGHOL*, determines if boards, on aggregate, hold on to their vested stock options until expiry year while these stock options are at least 40 percent in-the-money. Boards are again classified as overconfident if they are found to breach these limits at least once in the sample period.

Each of the determinants of overconfident boards are use individually in the parametric

[9]Five year to expiry and 67 percent in-the-money are levels determined by Malmendier and Tate (2005, 2008) using Hall and Murphy (2002) calibrations.

hazard specification defined earlier. The anti-dilutive implication of overconfident boards is determined by interacting the overconfidence dummy variable first with the dilutive stock options variable, and then with the segregated proportions of vested and unvested stock options.

3.2.4 Treasury regulation and buyback persistence

Similar to the overconfidence treatment, we exploit the incidence of an exogenous shock that clarifies the cost-relative benefit of anti-dilutive repurchases. This is illustrated in our third hypotheses defined earlier. As the change in regulation concerning treasury shares came into effect on December 1, 2003, we define a dummy variable, *TREASURY*, that takes the value of unity for all repurchases undertaken post regulation change. The anti-dilutive implication of this change is captured by interacting the dummy variable first with stock option holdings, and then the segregated proportions of vested and unvested stock options. The rest of the parametric hazard model, including *frailty*, remains the same as defined earlier.

3.3 Daily share repurchase distribution

Table 2 below illustrates the distribution of 9,129 daily repurchases between 1999 and 2010 for our sample firms.

[TABLE 2 GOES HERE]

Panel A shows the propensity with which repurchases were undertaken. Considering repurchase days independently, we can see that the number of repurchase days as a proportion of the total is serially declining relative to consecutive repurchase days, with over 36 percent of sample repurchase data concentrated around repurchase days lasting more than 22 consecutive days. We cluster repurchase days based on consecutive repurchase trading days to gain an understanding of the distribution of repurchases. The table illustrates how the distribution changes, with around a third of the sample transactions occurring as a single repurchase day. Similarly, around 70 percent of the repurchase transactions occur within five consecutive days. In this context, we find that almost all firms in our sample repurchase shares as a single transaction day, while about a third continue to repurchase shares consecutively for over a month.

In Panel B, we can see the yearly distribution of daily repurchases illustrated over the aggregate sample. The distribution of the sample suggests that repurchases have been concentrated in the years after the introduction of the treasury shares provision in 2003. This trend is visible for the aggregate measures of number of repurchase days, number of shares repurchased and the value of repurchase for the sample firms. It is worth pointing out that while the number of sample firms in our study is smaller than that used by Oswald and Young

(2008), the aggregate value of shares repurchased is more than double the size of their study, even after adjusting for length of sample period. Panel B also shows the yearly distribution of repurchase continuity over our sample period. The distribution points to increased continuity after change in treasury regulation, and relatively lower after the market decline in 2008. By measure of percentage of low continuity clusters, a similar trend is also found while a relatively large proportion of the sample conduct their buybacks more frequently.

3.4 Descriptive statistics

Table 3 below details the summary means, medians and standard deviations of the variables across the sample and sub-samples of this study.

[TABLE 3 GOES HERE]

Column (1) of Table 3 presents the descriptive statistics of all sample firms in our study, while column (2) shows the same statistics for the sub-sample that are repurchasing firms. Columns (3) and (4) segregate the repurchase sample data by low and high buyback continuity.

Statistics suggest that repurchasing firms are on average larger (proxied by firm market value) and with more investment opportunities (proxied by firm market-to-book ratio). These statistics are in line with agency theory expectations of larger firms choosing to repurchase shares as they transition to a mature stage (Grullon and Michaely, 2004). These differences are mimicked when looking across the segregated sample based on persistence. Repurchase observations that occur with increased continuity are found to be similar to the aggregate repurchase sample, while also showing statistically significant differences to its counterpart.

Repurchasing firms are found to exhibit lower volatility, spread and returns relative to the full sample, while also indicating managers with lower option holdings (unvested and vested). Such low levels of option holdings by repurchasing firms is found to differ across the segregation of continuity. We find that low continuity firms hold above sample mean and median of option holdings (vested and unvested). This would suggest that if repurchases have an anti-dilution motive, low continuity buyback firms should generate better returns to shareholders. We study these implications next using the methodologies defined earlier.

4 Empirical findings

4.1 Daily returns around buyback events

Using the methodologies described earlier, we first ascertain the importance of buyback continuity and option holdings by examining the returns generated by shareholders around repurchase events. This is done using the four-factor model described in eq. (1) and then estimating the abnormal and cumulative returns. We illustrate our findings starting from Table 4 below.

[TABLE 4 GOES HERE]

Columns (2) through (7) show the event window returns for all share repurchases in the sample. Results indicate that average abnormal returns prior to buybacks are statistically insignificant from zero for most of the days except the immediate day prior to repurchase. Returns are seen to decline 24 basis points on average, which is statistically significant using both two-sided t and ranksum tests. Firms are found to react to this negative drift in returns by repurchasing shares. Event day returns show a statistically significant (1 percent) positive return on average for buybacks undertaken with varying continuity. However, contrary to prior findings of a positive drift in share prices post-repurchase events (Ikenberry et al., 1995; Peyer and Vermaelen, 2009), our sample does not show any statistically significant trend in mean return past repurchase days. The median returns is seen to drift negatively for the five trading days examined (except event day 4), but is statistically inconsistent across post-repurchase days. Observing the cumulative effect, we do observe a negative trend when examining the returns in a two-day window pre and post-buyback days. This, however, is sensitive to the window of cumulative returns observed, suggesting that the buyback transaction effect is absorbed by the announcement day.

We further examine if these observed returns vary by how repurchases are implemented. We split consecutive repurchase days into low and high continuity groups. Low continuity repurchases are described as single buyback days, while high continuity events are repurchases that are consecutively implemented for two or more trading days. Columns (8) through (13) shows the results for low continuity, while columns (14) through (19) does the same for high continuity repurchases. Results for both continuity sets show similar trends prior to repurchase event, which are largely insignificant. However, the returns are more negative and statistically significant (1 percent) for the high continuity group, yielding 28 basis points lower return prior to buybacks. The cumulative effect for high continuity group consistently indicates a lower return prior to repurchase up to an event window of three-days pre and post-buybacks. These returns weakly rebound on event days (10 percent statistical significance) and are seen to drift positively briefly post-repurchase, but again are not different from zero. High continuity group again show a consistency in event-day positive returns up to the same event day groupings, but lose their significance in longer windows. Low continuity buybacks, on the other hand, generate an above sample mean reaction on event days, yielding 24 basis points higher returns. This, however, does not seem to hold when accounting for the cumulative effect.[10] To better understand the significance of these results over differential repurchase behaviour, we use the multi-variate, cross-sectional specification of eq. (2) described earlier. This framework helps control for a wide range of firm-specific factors that might drive the returns generated around

[10]Untabulated inter-sample difference in medians of post-buyback returns in low and high continuity groups suggest significant variation in market reaction, which we explore in a cross-sectional setup.

a repurchase event, while also observing the significance of variability in buyback behaviour. Our findings for this are shown in Table 5 and 6 below.

[TABLE 5 GOES HERE]

In Table 5, we regress event day average abnormal returns (CAAR(0,0)) and post-repurchase cumulative returns on firm-specific control variables. Our variables of interest are the dummy classification of *Continuity* and option holdings, the latter of which is assessed both in aggregated and segregated forms. To help differentiate the significance of single buy-back events against the rest, we evaluate the continuity of buybacks using its dummy and continuous classifications. The dummy variable follows the low and high continuity categorisation, while the continuous measure is the actual number of consecutive repurchase days in an event cluster, scaled by the average number of trading days in a calendar year (252).[11] Regression results of event day returns (columns 1 and 2) suggest that the continuity of buybacks contribute insignificantly to the market reaction of such events. This is different to the univariate results in Table 4 wherein low continuity buybacks are seen to drive the mean sample buyback returns. When examining the post-event window, we find market reaction differ. The dummy continuity variable is significant for cumulative returns up to 3 days after buyback events, implying a negative cumulative return of around 45 basis points. The intuition is similar when observing the continuous variable of continuity in Table 6 below, which suggests a positive association with post-buyback cumulative returns.

Observing the aggregate and segregated option holdings demonstrates opposing effects on buyback returns on event and post-event days. A negative sign on the coefficient estimates of vested and aggregate holdings quantifies to 13 to 10 percent negative impact on cumulative returns on buyback days, respectively. This effect reverses in the post-buyback period as unvested grants are inconsistent in their effect on CAARs, while vested grants show a consistently negative effect, implying a 50 percent effect on average returns for a standard deviation increase in the variable. This suggests that the anti-dilutive benefit of buybacks to shareholders is limited if vested grants are an increasing proportion of total shares outstanding. As for the controls used, firm size, volatility and dividend payout variables are largely inconsistent in their association with cumulative returns. However, lagged returns show a negative association to our dependent variable that indicates the response of buybacks relative to six months prior firm performance. This indicates the importance of the variable on not just buyback days, but also post-buyback reactions. Control variables of investment opportunity and trading spread are economically and statistically insignificant in all regression specifications.

[TABLE 6 GOES HERE]

[11] We undertake a Hausman test (Baltagi, 2008) for endogeneity of the *Continuity* variable to ensure that contemporaneous returns are not driving the continuity of buybacks. Under the null hypothesis of no endogeneity, we fail to reject it and are able to treat this parameter as exogenous.

We further substantiate the observed relationship between buyback continuity and returns post-repurchase events using the continuous buyback continuity parameter. Table 6 above shows our findings, which seems to mimic our earlier findings from Table 5. The difference we observe in the continuity parameter is a weaker statistical significance on the post-buyback cumulative returns. Considering the significance of -1 event day, we test the significance of the continuous variable on CAARs over the event window of -1 to +1 days. Untabulated results here indicate a weak but positive statistical significance. Option variables show similar economic significances, with the negative effect of vested grants on post-buyback returns remaining strong with similar economic effects. Other control variables indicate similar importance across specifications as in Table 5, although we do now observe a weak significance of the dividend payout parameter.

Overall, event study results of buyback returns suggest that while event day positive buyback returns follow negative trends, these effects largely disappear when considering the nature of buyback implementation. Buybacks that are more strategic (low continuity) show signs of negative return trends post buyback events after controlling for various cross-sectional parameters. Post-buyback negative returns are also observed for stock option grants that are vested, while marginally positive when options are unvested, implying a non-linear behaviour in the segregation. These findings substantiate the argument that shareholder reaction to buybacks depends not just on how they are implemented, but also on the vesting stage of option grants that buybacks fulfil anti-dilutive motives. This provides the motivation to explore this relationship between buyback behaviour and dilutive stock options further below.

4.2 Repurchases and the anti-dilution effect

The findings above suggest that repurchase flexibility entitles firms to implement their payout programs with varying continuity, which effect anti-dilution of stock option grants and consequently on shareholder returns. This indicates that the motive behind buyback implementation varies depending on the continuity of share repurchases. To capture this aspect of buyback flexibility, we examine if share repurchases act as an anti-dilutive tool to mitigate the cost apparent when incentivising managers through dilutive stock options grants. This intuition is formulated in our first hypothesis discussed earlier, which we now test using the specifications of eq. (3) and (4). We present the findings in Table 7 below.

[TABLE 7 GOES HERE]

Columns (1) and (2) above show the results using the Cox semi-parametric proportional hazard rate model, while columns (3) and (4) do the same using the parametric Weibull distribution model. Both models indicate a statistically significant positive relationship between aggregate dilutive stock options and the incidence of share repurchase. The mean hazard rate of a firm repurchasing shares is in the range of 1.46 to 1.70 for firms with outstanding stock options.[12] Segregating the aggregate stock options measure into vested and unvested components yields some difference between the parametric and non-parametric models. The Weibull model indicates an indifferent hazard rate of 1.02 for increases in vested grants, while unvested options increase the hazard of buybacks by 1.63. This indicates that the aggregate buyback behaviour is driven largely by limits to option vesting conditions.

The distribution property of the parametric Weibull hazard rate model shows some differences in coefficients for control variables used in the model. Lagged returns and volatility variables invert their association to buyback continuity relative to the semi-parametric Cox model. The parametric model indicates that small firms and those with more investment opportunities are more likely to increase their buyback consistency. Repurchase continuity is also driven by lower past returns and volatility, which support the undervaluation and liquidity arguments. In contrast, however, we find average spreads to be higher suggesting firms trade in illiquidity, acting as contrarian buyers of their shares. The dividend payout ratio also suggests an increasing hazard (1.65) of share buybacks, which supports the dual payout channel arguments of Grullon and Michaely (2002) as the most viable payout choice.

[TABLE 8 GOES HERE]

We further test the anti-dilutive benefit of share repurchases by examining the effect of dilutive stock options at varying levels of buyback continuity. We do so by investigating, individually, the anti-dilutive effects for continued repurchases of up to 5 trading days. Table 8 above shows our findings when the sample is constrained by number of consecutive repurchase days.[13] In each case, the sample is controlled by censoring firms with no repurchases, or right-censoring when buybacks falls under the limit of window being examined.[14] Panel A shows the results for the aggregate level of stock options, while Panel B does the same for vested and unvested stock options. While Panel A illustrates a lack of anti-dilutive objective behind buybacks undertaken for less than 4 trading days, coefficients for unvested grants in Panel B supports the immediate anti-dilutive arguments. The results also indicate the importance of stock options in the anti-dilutive objective behind buybacks as repurchasing shares when options are vested does not always translate to shareholder benefits. Similarly, we also see anti-dilution effects for unvested stock options stronger than vested, with the latter only weakly significant on the fifth repurchase day to be anti-dilutive.

[12] Tables show the coefficients determined from the hazard rate model. Hazard rates are computed by exponentiating the observed coefficients. We determine the hazard rate of a marginal effect of a standard deviation shift in a variable by exponentiating the product of the variable coefficient and one of its standard deviation.

[13] A semi-parametric Cox proportional hazard model is used in this segmented analysis as the properties of parametric model will be restrictive in a smaller sub-sample and thus will fail to apply.

[14] For instance, in Event5 examining up to 5 repurchase days, all non-repurchasing firms and firms that repurchase for only 4 trading days are censored.

The model coefficients observed for the control variables are quite different to the aggregate model in Table 7. We find larger firms more likely to be engaged in shorter buyback continuity, while the association of the investment opportunity parameter is seen changing from positive to negative after two consecutive buyback days. We also don't find any consistency in the estimates of lagged returns, which seems to indicate that short-continuity buybacks may not follow a negative trend in six-month returns.

In summary, the above findings indicate an anti-dilutive motive behind repurchases, which is found to be increasing in the proportion of stock options outstanding. This result is similar to the intuition of Fenn and Liang (2001) and Kahle (2002), but confirmed over buyback continuity and time between repurchases. Additionally, this anti-dilutive effect is found to be greater for unvested stock options as they are seen to be mitigating the implied dilution cost while also optimising the buyback flexibility benefit to shareholders. Hence, these findings reject the null argument of our first hypothesis in favour of the alternative.

4.3 Anti-dilutive repurchases and board overconfidence

The analysis above suggests that share repurchases can be anti-dilutive, with the effect greater when stock options are unvested. To better ascertain the consistency of this relationship, we expose the specification used earlier to a time-invariant treatment variable that distinguishes the anti-dilution effect between different groups of stock option users. Malmendier and Tate (2005, 2008) make use of classification of managers based on their overconfidence traits to distinguish their investment outlook. They identify overconfident managers as more likely to overestimate investment returns and synergies from mergers. In this context, segregating boards based on their overconfidence levels should differentiate their attitude to buybacks. This is formalised in our second hypothesis, which we now test using the same specification of the parametric Weibull hazard rate model (eq. 4). We present the findings in Table 9 below.

[TABLE 9 GOES HERE]

The table above shows the results including a dummy variable identifier for overconfident boards (*HOL67*). We interact this variable with the continuous stock options variable that determines the significance of difference between boards based on their overconfidence classification. In columns (1) and (2), we see that overconfident boards reduce the continuity of repurchases, indicating a statistically significantly 60 percent lower likelihood of repurchases relative to boards not classified as overconfident. The stock options variable continues to indicate increasing continuity, which agrees with our earlier findings of anti-dilutive benefits. We see the interaction of the two variables indicating a statistically significant (1 percent) difference between boards. Increase in aggregate option grants lowers the continuity of buybacks for overconfident boards by 20 percent more than non-overconfident boards, suggesting motives that are not anti-dilutive in nature. This indicates that there is an intention either to try time the market or delay the buyback until closer to expected exercise of stock options.

Similar results are observed when we segregate the stock options variable into vested and unvested categories. Column (3) shows similar levels of hazard rates for both vesting categories seen previously in Table 7. However, once we interact the two variables with the overconfidence dummy (column 4), we find overconfident boards significantly reducing (40 percent lower) anti-dilutive buybacks when options are vested, while anti-dilution for unvested stock option are similar between overconfident classifications. Non-overconfident boards show anti-dilutive relations similar to the average sample, with the effect greater for unvested stock options. However, while the anti-dilutive effect of vested stock options is positive for non-overconfident boards, we find the main effect of the same variable for overconfident boards (sum of *HOL67* and vested stock options) to be negative. This indicates that overconfident boards are more prone either to time or delay buybacks when their stock options vest. The effect and significance of other control variables is similar to that observed after Table 7.

[FIGURE 1 GOES HERE]

Figures 1 and 2 illustrate the significance of differences in anti-dilutive effect between classifications of overconfident boards. In Figure 1, we see the survival probability of aggregate stock options, split based on *HOL67* dummy. The survival curve plots the time-varying (number of trading days) probability of a firm repurchasing shares during its lifetime. Hence, lower curves indicate higher buyback probability for shorter time scales, while a higher curve shows a lower probability to repurchase, with greater chance of delay and timing. Here we see that non-overconfident boards display a consistently lower survival probability relative to overconfident boards. At 50 percent survival probability, the lag between the two overconfidence categories is approximately 250 trading days, indicating a lag of almost a year for overconfident boards. This illustrates the significance of option holdings in buyback decisions of boards based on their overconfidence categorisation.

[FIGURE 2 GOES HERE]

Figure 2 above shows a similar survival probability curve, but we split the curve based on level of stock option holdings. The sensitivity is based on firms with either no outstanding grants or those with repurchase sample median level of stock option holdings. We segregate this analysis for both aggregate holdings of stock options, and holdings based on vesting conditions. Panel A shows that while overconfident boards continue to indicate higher survival probability (lower hazard rate), the level of stock option holdings does not change this relationship. The existence of stock option grants is seen to lower the survival probability for both groups, highlighting an anti-dilutive motive. Similar differences between overconfidence groups exist based on stock option vesting conditions. However, the survival probability is indistinguishable between different levels of vested grants, while at unvested levels, granting new stock options increases the hazard rate for both overconfidence groups.

[TABLE 10 GOES HERE]

We further test the reliability of these findings by using an alternative overconfidence measure. The *LONGHOL* categorisation of Malmendier and Tate (2005, 2008) is based on the ability of managers to hold on to in-the-money stock options until expiry year. We replicate the results by interacting the *LONGHOL* dummy with stock option variables. Table 10 above shows our results, which indicate similar findings with regards to the anti-dilutive effects. The interaction variables of aggregate stock options and those based on vesting conditions indicate a statistically significant (1 percent) difference between overconfidence groupings of boards. The anti-dilutive effect continues to be valid for unvested stock options, while vested grants are seen to lower the continuity of buybacks. A difference visible between this result and HOL67 interactions is the effect of unvested grants on buyback continuity. The interaction variable indicates a statistically significant higher hazard rate of 3.84 for unvested grants by overconfident boards, relative to non-overconfident boards. Additionally, the *LONGHOL* coefficient suggests an increasing hazard rate of repurchases for overconfident boards, which might be driven by the fact that the variable proxies for holdings held until expiry year, prompting more buybacks before options expire.

In summary, our findings here suggest a significant difference between boards driven by their motive to anti-dilute the outstanding stock option grants. The anti-dilutive effect is again stronger when stock options are unvested, while vested grants prompt timing behaviour. Such lower persistence buybacks render continuing shareholders worse-off due to lower cumulative returns around these buyback events. Hence, our results reject the null argument of the second hypothesis in favour of the alternative.

4.4 Anti-dilutive repurchases and Treasury regulation

The benefit of using the UK institutional setting for this study is not just concerning the details of daily buyback transactions disclosed by firms, but also a change in buyback regulation accounting for Treasury shares. As mentioned earlier, prior to December 1, 2003, all repurchased shares had to be cancelled, thus reducing the issued share base. This prompted firms to access capital markets for secondary issues to meet option exercises, thus diluting holdings of existing shareholders. This was seen as costly to firms, leading to the introduction of regulation enabling the ability to hold repurchased shares in Treasury. Treasury shares entitle firms, amongst many objectives, to meet stock option exercises of employees without issuing new equity. Hence, if the new regulation enhances the anti-dilutive benefits of repurchases, we should expect buyback continuity to increase for unvested stock options. We declare this intuition in our third hypothesis, which we now test using the same specification of the parametric Weibull hazard rate model (eq. 4). We present the findings in Table 11 below.

[TABLE 11 GOES HERE]

Results above display the interaction between our option parameters and a time-variant dummy, *TREASURY*, that separates the before-after regulation-change periods. For the aggregate option holdings (columns 1 and 2), we find the anti-dilutive effect is driven largely by holdings prior to change in regulation. The interaction variable, capturing the significance of difference in anti-dilutive effects between before and after change in regulation, shows a statistically significant (1 percent) negative change in anti-dilutive relationship between stock options and buyback continuity. The main effect of stock options after the change in regulation suggests a significantly lower hazard rate of 0.05 compared to 2.80 prior to regulation change, both for a standard deviation change in stock options outstanding.[15] This suggests that the change in regulation reduced the continuity in buybacks for aggregate option holdings. However, in light of our anti-dilutive argument, we expect the non-linear effects between vested and unvested grants to shed light on the effect of change in regulation on buyback behaviour.

To clarify this finding, we explore if the stock option vesting schedule shifted buyback behaviour after the change in regulation. Without any interaction with the *TREASURY* variable, we continue to see (column 3) the stronger anti-dilutive effect with respect to unvested stock options. On incorporating the interaction effect, we find that the reverse was true prior to regulation change. Buyback continuity was driven largely by vested stock options, while unvested grants significantly reduced buyback occurrence. This isn't surprising given firms were unable to hold shares in Treasury, shifting repurchase transaction prior to intended stock option exercise. This behaviour changed post-regulation as we observe significantly higher buyback activity for unvested stock options after Treasury change came in to effect, relative to prior periods. Similarly, vested grants significantly reduced continuity in buyback activity, indicating greater likelihood of repurchase timing. Consistent with our results in Table 7, we find buyback continuity to be driven by firms that are small and with more investment opportunities. We continue to observe lower past returns and volatility with higher average spreads supporting undervaluation and contrarian arguments.

[15] The main effect is stock options post-regulation change is computed by taking the sum of coefficients of *TREASURY* and its interaction with aggregate stock option holdings. We then exponentiate the product of this sum and the standard deviation of latter variable to derive the hazard rate.

5 Conclusion

Corporate payout policy has become reliant upon share buybacks due to the flexibility they attribute to managers. While the significance of repurchases in addressing various firm objectives has been widely explored (Farre-Mensa et al., 2014), their capacity to meet firm stock option exercise commitments remains unclear. Primarily, contradictory evidence by Kahle (2002) and Fenn and Liang (2001) highlights a disagreement on the significance of level and nature of managerial stock option grants in influencing firm buybacks. Furthermore, the non-committal nature of share buyback does not guarantee anti-dilution of stock options at the time of announcement of such programs. Our study aims to address these concerns by exploring how buyback behaviour and the level and nature of stock option holdings influence shareholder returns around buyback transactions, and if the dynamics of stock options influence buyback implementation to ensure an anti-dilutive motive.

Using a unique sample of daily repurchase transactions from the UK, we find that on average buybacks follow a significant decline in returns of 24 basis points up to 1 trading day prior to the event. Upon disclosure, post-buyback returns are significantly lower (median), driven largely by buybacks that occur with lower frequency. This finding holds even in the cross-section, indicating lower post-buyback two-day cumulative returns of 49 basis points for single repurchase transaction days. Similarly, post-buybacks returns are lower when firms hold large vested grants while irregularly positive for unvested stock options, implying a different perception of buybacks at different vesting stages of option grants. These findings are robust to clustering of events by firms and adjustment for various firm attributes.

We investigate the rationale for the differential impact of option vesting schedule using an anti-dilutive motive of buybacks. Repurchase flexibility is influenced by the vesting conditions of dilutive stock options, which limits the anti-dilutive benefits of buybacks. Our results indicate a 24 percent higher probability (1.63 odds ratio) of increased repetition of repurchases when stock options are unvested compared to when they vest (1.02 odds ratio), for a standard deviation change in either variable. The anti-dilutive benefits start to take effect for aggregate option holdings when repurchases are undertaken for 4 or more trading days. Unvested grants are largely influential in the increased repetition of anti-dilutive buybacks, which are effective from the first buyback day. Alternatively, the effect of vested grants is delayed for buybacks with at least five transaction days.

To establish consistency in this finding, we explore the effect of dilutive stock options and their implication on share buybacks differentiated by overconfidence classification of boards and a change in Treasury regulation that lowered capital cost for increased flexibility. Our findings show that overconfident boards are more likely to try time the market, resulting not only in fewer repurchase days but, in some instances, are delayed until the time when options vest. We also find a significant shift in buyback behaviour of repurchasing firms around changes in Treasury regulation. We observe that while the regulation enabled greater flexibility in buybacks to ensure anti-dilutive benefits from unvested stock options, it did not completely suppress a firm's ability to delay or time buybacks around option vesting times, which can have consequential impact on shareholders.

Our study is most closely related to the literature on the relationship between share buyback and stock options (Fenn and Liang, 2001; Kahle, 2002). While the dilution implication from stock options is clear (Eberhart, 2005), empirical evidence on the anti-dilutive benefits of repurchases is limited. Anti-dilutive arguments are explored by (Dittmar, 2000), but this study is unique in illustrating the limits of buyback flexibility and the conditions under which these benefits are likely to be realised. Our study is also seen to extend the evidence surrounding the frequency of buybacks (Dittmar and Field, 2015) by using a more refined daily transaction data to explore the likelihood of continued repurchase. Finally, we also complement the results of Bonaimé et al. (2016) who suggest repurchases potentially can be expensive and not necessarily beneficial to shareholders. Future research could incorporate the dilutive effect of all employee stock option grants and the repurchase behaviour they exert.

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Table 1: Sample selection criteria

This table describes the selection criteria used to determine the sample data for the study. Panel A of the table illustrates the breakdown of the unique number of firms used in the study. Identification of firms is done using data from Securities Data Company (SDC) database and subsequently filtered to arrive at a unique set of firms. This is done due to the multiplicity of announcements by each firm in SDC not captured by database. Panel B details the composition of the sample data after merging with BoardEx data on option parameters. Since the BoardEx data begins in 1999, all data prior to the period identified through SDC is lost.

Panel A: Identification of firms with authorities and implementations

Description	Number of Firms/Days
Number of repurchase events identified by SDC to occur in the UK between 1990 and 2010	640
Less:	
- Events attributed to financial and utility firms	338
	302
- Duplicate entries of repurchase intentions to identify unique list of firms	62
	240
- Firm identifiers not available to match information on Datastream/Worldscope	36
	204
- Annual report information not available in PI	8
Final unique number of firms identified to have obtained a repurchase authority	196
Subset of authority firms that repurchase during the period of 1990 to 2010	152
Number of repurchase days for the repurchasing firms during the period of 1990 to 2010	11,754

Panel B: Composition of sample after merging with BoardEx

Description	Number of Firms/Days
Number of firms in the BoardEx universe	1,810
Less:	
- Number of firms lost after merging with SDC-identified firms	1,691
Total number of firm identified out of 196 in the sample period from 1999 to 2010	119
Subset of authority firms that repurchase during the period of 1999 to 2010	80
Number of repurchase days for the repurchasing firms during the period of 1999 to 2010	9.214

Table 2: Repurchase distribution

The following table shows the distribution of daily repurchase transactions in the UK. Panel A illustrates the distribution based on consecutive repurchase days, while Panel B gives more detailed distribution statistics on a yearly basis. Panel B, additionally, also segregates the yearly distribution of repurchase based on continuity of transactions. Continuity is defined as consecutive repurchase days, with low continuity meaning repurchase undertaken for just one trading day, and vice versa.

Panel A

Consecutive repurchase days	1	2	3	4	5	6	7	8	9	10	11-22	>22	Total
% of repurchase sample	5.54	5.39	4.63	4.64	3.89	3.48	2.61	3.33	2.86	2.85	24.53	36.25	9,129
% of cluster sample	34.03	16.54	9.48	7.13	4.77	3.56	2.29	2.56	1.95	1.75	10.02	5.92	1,487
% of repurchasing firms	93.75	65.00	46.25	37.50	36.25	31.25	22.50	25.00	26.25	22.50	32.50	30.00	80

Panel B

Years	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
Buyback Aggregate:													
No. of repurchase days	150	382	373	556	847	1,013	1,244	1,334	1,569	1,376	138	147	9,129
No. of repurchase clusters	67	94	99	134	162	191	125	155	191	186	38	45	1,487
No. of repurchasing firms	15	19	14	17	22	30	24	27	32	35	15	11	80
No. of shares repurchased (in mln.)	407	1,483	484	598	951	3,011	5,451	2,326	1,071	1,454	28	40	17,304
Value of shares repurchased (in GBP mln.)	1,840	3,641	1,762	3,292	3,629	5,430	13,084	6,497	6,435	4,586	186	320	50,702
Buyback Continuity:													
Mean continuity	2.24	4.06	3.77	4.16	5.22	5.30	9.95	8.61	8.21	7.40	3.71	3.20	
% of clusters that show low continuity	68.66	40.43	26.26	35.82	32.72	33.51	27.20	27.10	30.89	32.80	44.74	40.00	
% of repurchasing firms that show low continuity	100.00	68.42	71.43	82.35	81.82	86.67	75.00	77.78	75.00	77.14	73.33	81.82	

Table 3: Descriptive statistics

The following table shows the descriptive statistics of sample firms used in the study. The table shows sample means, medians (parentheses) and standard deviation (italics) segregated by continuity of transactions by repurchasing firms. Continuity is defined as consecutive repurchase days, with low continuity meaning repurchase undertaken for just one trading day, and vice versa. Statistical significance for repurchasing firms is based on comparison with the entire sample. Statistical significance of difference in low and high buyback continuity is based on sub-sample of repurchasing firms only. Inter-sample differences in mean (t-test) and median (Wilcoxon rank-sum test) are shown as ^{a}, ^{b} and ^{c} indicating 10%, 5% and 1% two-sided significance of difference from null, respectively. Definition of how variables are computed is provided in the Appendix (Table A1).

	All sample firms	Repurchasing firms	Continuity	
			Low	High
	(1)	(2)	(3)	(4)
Size	5,076	16,961^c	4,511^c	17,692
	(262)	(5,324^c)	(541^c)	(5,643)
	16,689	*27,823*	*17,179*	*28,154*
Investment opportunity	1.7050	1.9480^c	2.1550	1.9360
	(1.3400)	(1.6200^c)	(1.4460^c)	(1.6300)
	2.4480	*1.9770*	*3.3450*	*1.8650*
Volatility	0.3180	0.2450^c	0.2780^c	0.2430
	(0.2790)	(0.2150^c)	(0.2550^c)	(0.2110)
	0.1750	*0.1220*	*0.1300*	*0.1200*
Spread	5.6760	1.8540^c	5.1310^c	1.6620
	(2.5700)	(1.3440^c)	(2.7270^c)	(1.3110)
	13.5900	*4.1040*	*12.7300*	*2.7700*
Lagged return	0.0134	0.0076^b	0.0043	0.0078
	(0.0500)	(0.0485^c)	(0.0452)	(0.0485)
	0.3530	*0.2340*	*0.2860*	*0.2310*
Dividend payout	0.4680	0.4863^c	0.4584^c	0.4880
	(0.4848)	(0.5201^c)	(0.4645^c)	(0.5252)
	0.2836	*0.2169*	*0.2308*	*0.2160*
Shares repurchased	0.0000	0.0011^c	0.0059^c	0.0008
	(0.0000)	(0.0004^c)	(0.0010^c)	(0.0004)
	0.0012	*0.0064*	*0.0248*	*0.0025*
Total options	0.0103	0.0046^c	0.0089^c	0.0043
	(0.0031)	(0.0016^c)	(0.0036^c)	(0.0015)
	0.0178	*0.0010*	*0.0152*	*0.0096*
Unvested options	0.0038	0.0019^c	0.0029^c	0.0019
	(0.0003)	(0.0005^a)	(0.0001)	(0.0005)
	0.0143	*0.0066*	*0.0116*	*0.0062*
Vested options	0.0065	0.0027^c	0.0058^c	0.0025
	(0.0012)	(0.0007^c)	(0.0019^c)	(0.0007)
	0.0086	*0.0054*	*0.0072*	*0.0052*

Table 4: Analysis of returns around repurchase clusters

The following table shows the distribution of average and cumulative average abnormal returns around a repurchase cluster. The Carhart (1997) four-factor model is used to generate estimates of returns in an estimation window of -131 to -6 trading days prior to an event, using the following regression specification.

$$Return_t = \alpha + \beta_1 Market_t + \beta_2 SmallMinusBig_t + \beta_3 HighMinusLow_t + \beta_4 Momentum_t + \epsilon_t$$

where, *Return* is regression on different factors of market, size, value and momentum. Average abnormal returns (AAR) are determined based on difference in actual returns and ones based on parameter estimates from the model. Cumulative average abnormal returns ($CAARs$) are computed by cumulating $AARs$ over multiple groupings of consecutive event days. Columns (2) through (7) show the return distribution for all repurchasing firms; columns (8) through (13) shows the $AARs$ and $CAARs$ for low continuity repurchases while columns (14) through (19) show the same for high continuity buybacks. Continuity is defined as consecutive repurchase days, with low continuity meaning repurchase undertaken for just 1 day, and vice versa. *, ** and *** show two-sided statistical significance of difference to event day returns at 10%, 5% and 1%, respectively.

	N	All (N = 1435)						Low Continuity (N = 472)						High Continuity (N = 963)					
		AAR	CAARs					AAR	CAARs					AAR	CAARs				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
t-5 days	1435	0.0001					0.0001	-0.0001					-0.0001	0.0001					0.0001
		(-0.0006)						(-0.0010)						(-0.0003)					
t-4 days	1435	0.0003				0.0003	0.0003	-0.0001				-0.0001	-0.0001	0.0005				0.0005	0.0006
		(-0.0004)						(-0.0005)						(-0.0003)					
t-3 days	1435	0.0010*			0.0010*	0.0013	0.0013	0.0010			0.0010	0.0010	0.0009	0.0009			0.0009	0.0014	0.0015
		(-0.0002)						(-0.0001)						(-0.0003)					
t-2 days	1435	-0.0007		-0.0007	0.0002	0.0005	0.0006	-0.0013		-0.0013	-0.0002	-0.0002	-0.0003	-0.0005		-0.0005	0.0004	0.0009	0.0010
		(-0.0005)						(-0.0009)						(-0.0003)					
t-1 day	1435	-0.0024***	-0.0024***	-0.0031***	-0.0021**	-0.0018	-0.0018	-0.0014	-0.0014	-0.0027**	-0.0017	-0.0017	-0.0017	-0.0028***	-0.0028***	-0.0033***	-0.0024**	-0.0019	-0.0018
		(-0.0011***)						(-0.0010*)						(-0.0012***)					
Event days	1435	0.0011***	-0.0013*	-0.0020**	-0.0010	-0.0007	-0.0006	0.0024***	0.0010	-0.0003	0.0007	0.0007	0.0007	0.0005*	-0.0023**	-0.0028**	-0.0019*	-0.0014	-0.0013
		(0.0002**)						(0.0002**)						(0.0002)					
t+1 day	1413	0.0001	-0.0013	-0.0021*	-0.0011	-0.0009	-0.0007	-0.0008	0.0002	-0.0015	-0.0005	-0.0005	-0.0002	0.0005	-0.0018	-0.0023*	-0.0015	-0.0011	-0.0010
		(0.0000*)						(-0.0004)						(0.0002)					
t+2 days	1413	-0.0004		-0.0025**	-0.0016	-0.0013	-0.0012	-0.0017*		-0.0032*	-0.0022	-0.0022	-0.0019	0.0002		-0.0022	-0.0013	-0.0009	-0.0008
		(-0.0008**)						(-0.0014***)						(-0.0007)					
t+3 days	1413	-0.0005			-0.0021	-0.0018	-0.0016	-0.0002			-0.0024	-0.0024	-0.0021	-0.0006			-0.0019	-0.0015	-0.0014
		(-0.0008**)						(-0.0011**)						(-0.0006)					
t+4 days	1412	0.0002				-0.0017	-0.0015	0.0018				-0.0006	-0.0003	-0.0006				-0.0022	-0.0021
		(-0.0007)						(-0.0004)						(-0.0009)					
t+5 days	1412	-0.0007					-0.0022	-0.0015					-0.0018	-0.0003					-0.0024
		(-0.0009**)						(-0.0009*)						(-0.0008)					

Table 5: Cross-sectional analysis of post-repurchase cumulative average abnormal returns (CAARs): Continuity dummy

The following table shows the cross-sectional regression of post-repurchase cumulative average abnormal returns (CAARs). This table makes use of the dummy classification of *Continuity* of share buybacks, defined as unity of repurchases occur for just one trading day, else zero if for two or more consecutive trading days. The following specification is used in the analysis:

$$CAAR_i = \beta_1 ContinuityDummy_i + \beta_2 \Delta Options_i + \beta_3 Size_i + \beta_4 InvestmentOppurtunity_i + \beta_5 Volatility_i + \beta_6 Spread_i + \beta_7 LaggedReturns_i + \beta_8 PayoutRatio_i + \epsilon_i$$

The analysis is presented for returns generated on transaction (including disclosure) day, defined as event day, and all post-event days in the event window. The analysis also includes the effect of *Options* and its segregation in to vested and unvested grants on post-repurchase returns. Definition of all variables, including control variables are as described in the Appendix (Table A1). *, ** and *** refer to a two-sided t-test representing 10%, 5% and 1% statistical significance.

	Dependent variable: CAAR(0,0)		Dependent variable: CAAR(1,2)		Dependent variable: CAAR(1,3)		Dependent variable: CAAR(1,4)		Dependent variable: CAAR(1,5)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Continuity dummy	0.0017	0.0016	-0.0049**	-0.0047**	-0.0041*	-0.0038*	-0.0009	-0.0006	-0.0021	-0.0017
	(1.61)	(1.51)	(-2.62)	(-2.51)	(-1.87)	(-1.75)	(-0.35)	(-0.23)	(-0.78)	(-0.65)
Options	-0.0630*		-0.1306		-0.1259		-0.0718		-0.0416	
	(-1.82)		(-1.06)		(-0.77)		(-0.50)		(-0.24)	
Unvested options		-0.1563**		0.1550		0.2127		0.3042*		0.3476*
		(-2.22)		(1.67)		(1.15)		(1.76)		(1.75)
Vested options		0.0058		-0.3364**		-0.3652**		-0.3520**		-0.3747**
		(0.14)		(-2.07)		(-2.00)		(-2.24)		(-2.20)
Size	-0.0001	-0.0001	-0.0011**	-0.0010**	-0.0008	-0.0007	-0.0006	-0.0005	-0.0005	-0.0004
	(-0.46)	(-0.62)	(-2.27)	(-2.14)	(-1.09)	(-0.93)	(-0.91)	(-0.73)	(-0.68)	(-0.49)
Investment opportunity	-0.0001	-0.0001	-0.0001	-0.0001	-0.0002	-0.0002	0.0002	0.0002	0.0002	0.0002
	(-0.81)	(-0.85)	(-0.25)	(-0.28)	(-0.54)	(-0.54)	(0.57)	(0.45)	(0.41)	(0.29)
Volatility	0.0035	0.0034	-0.0111	-0.0106	-0.0153	-0.0147	-0.0246	-0.0239	-0.0263*	-0.0255*
	(0.86)	(0.83)	(-1.31)	(-1.34)	(-1.36)	(-1.37)	(-1.60)	(-1.61)	(-1.75)	(-1.73)
Spread	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001
	(1.28)	(1.16)	(0.49)	(0.75)	(0.28)	(0.50)	(-0.27)	(-0.07)	(0.85)	(1.08)
Lagged return	-0.0070***	-0.0069***	-0.0160***	-0.0165***	-0.0246***	-0.0251***	-0.0334***	-0.0339***	-0.0374***	-0.0381***
	(-4.13)	(-3.98)	(-3.87)	(-4.27)	(-4.75)	(-5.01)	(-6.27)	(-6.50)	(-6.32)	(-6.50)
Dividend payout	0.0000*	0.0000*	0.0001**	0.0001**	0.0001*	0.0001*	0.0001	0.0001	0.0001	0.0001
	(1.67)	(1.67)	(2.28)	(2.31)	(1.74)	(1.75)	(1.63)	(1.64)	(1.63)	(1.62)
Constant	-0.0010	-0.0007	0.0085	0.0074	0.0057	0.0045	0.0052	0.0038	0.0043	0.0029
	(-0.38)	(-0.25)	(1.64)	(1.49)	(0.76)	(0.60)	(0.61)	(0.45)	(0.45)	(0.30)
F-stat	4.9193	7.3019	4.8404	5.9140	5.1742	4.6915	7.9991	7.0984	8.8154	7.9367
p-value	0.0001	0.0000	0.0001	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000
Adjusted R2	0.0388	0.0402	0.0275	0.0299	0.0386	0.0408	0.0483	0.0504	0.0530	0.0554
N	1383	1383	1358	1358	1358	1358	1358	1358	1358	1358

Table 6: Cross-sectional analysis of post-repurchase cumulative average abnormal returns (CAARs): Continuity continuous

The following table shows the cross-sectional regression of post-repurchase cumulative average abnormal returns (CAARs). This table makes use of the continuous classification of *Continuity* of share buybacks, defined as the number of consecutive repurchase days in a cluster, scaled by total number of trading days in a year (assumed to be 252). The following specification is used in the analysis:

$$CAAR_i = \beta_1 Continuity_i + \beta_2 \Delta Options_i + \beta_3 Size_i + \beta_4 InvestmentOppurtunity_i + \beta_5 Volatility_i + \beta_6 Spread_i + \beta_7 LaggedReturns_i + \beta_8 PayoutRatio_i + \epsilon_i$$

The analysis is presented for returns generated on transaction (including disclosure) day, defined as event day, and all post-event days in the event window. The analysis also includes the effect of *Options* and its segregation in to vested and unvested grants on post-repurchase returns. Definition of all variables, including control variables are as described in the Appendix (Table A1). *, ** and *** refer to a two-sided t-test representing 10%, 5% and 1% statistical significance.

	Dependent variable: CAAR(0,0)		Dependent variable: CAAR(1,2)		Dependent variable: CAAR(1,3)		Dependent variable: CAAR(1,4)		Dependent variable: CAAR(1,5)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Continuity	-0.0056	-0.0052	0.0298*	0.0288*	0.0232	0.0220	0.0148	0.0135	0.0274	0.0260
	(-1.38)	(-1.30)	(1.99)	(1.92)	(1.32)	(1.27)	(0.67)	(0.61)	(0.96)	(0.92)
Options	-0.0654*		-0.1253		-0.1214		-0.0712		-0.0400	
	(-1.81)		(-0.98)		(-0.73)		(-0.50)		(-0.23)	
Unvested options		-0.1651**		0.1818**		0.2348		0.3056*		0.3541*
		(-2.38)		(2.00)		(1.28)		(1.75)		(1.81)
Vested options		0.0070		-0.3428**		-0.3705*		-0.3523**		-0.3762**
		(0.17)		(-2.02)		(-1.97)		(-2.24)		(-2.20)
Size	-0.0002	-0.0002	-0.0009**	-0.0008*	-0.0006	-0.0005	-0.0006	-0.0005	-0.0005	-0.0004
	(-1.13)	(-1.28)	(-2.00)	(-1.83)	(-0.84)	(-0.68)	(-0.94)	(-0.78)	(-0.71)	(-0.54)
Investment opportunity	-0.0001	-0.0001	0.0000	0.0000	-0.0001	-0.0002	0.0002	0.0002	0.0002	0.0002
	(-0.99)	(-1.04)	(-0.08)	(-0.13)	(-0.41)	(-0.43)	(0.62)	(0.48)	(0.47)	(0.35)
Volatility	0.0028	0.0027	-0.0088	-0.0084	-0.0134	-0.0129	-0.0240	-0.0235	-0.0251*	-0.0244
	(0.70)	(0.67)	(-1.05)	(-1.07)	(-1.21)	(-1.22)	(-1.57)	(-1.58)	(-1.68)	(-1.66)
Spread	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001
	(1.37)	(1.24)	(0.13)	(0.42)	(0.06)	(0.31)	(-0.29)	(-0.08)	(0.81)	(1.06)
Lagged return	-0.0070***	-0.0068***	-0.0162***	-0.0167***	-0.0247***	-0.0252***	-0.0334***	-0.0340***	-0.0375***	-0.0381***
	(-4.08)	(-3.95)	(-3.89)	(-4.33)	(-4.78)	(-5.07)	(-6.29)	(-6.53)	(-6.38)	(-6.57)
Dividend payout	0.0000*	0.0000*	0.0001**	0.0001**	0.0001*	0.0001*	0.0001	0.0001*	0.0001*	0.0001*
	(1.72)	(1.71)	(2.28)	(2.32)	(1.73)	(1.75)	(1.67)	(1.68)	(1.69)	(1.69)
Constant	0.0007	0.0010	0.0037	0.0028	0.0017	0.0007	0.0043	0.0032	0.0023	0.0012
	(0.28)	(0.38)	(0.80)	(0.61)	(0.24)	(0.10)	(0.52)	(0.40)	(0.27)	(0.14)
F-stat	4.9162	6.8685	4.8898	6.7797	5.2075	4.7399	8.5217	7.4333	8.1274	7.4178
p-value	0.0001	0.0000	0.0001	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000
Adjusted R2	0.0354	0.0371	0.0239	0.0266	0.0367	0.0392	0.0484	0.0506	0.0531	0.0557
N	1383	1383	1358	1358	1358	1358	1358	1358	1358	1358

Table 7: Hazard model of dilutive option holdings on repurchase continuity
This table shows the results for semi-parametric and parametric hazard-rate models, using the following Cox and Weibull model specification, respectively.

$$h_{ik}(t|\theta_i) = \theta_i h_0(t) exp(\beta \mathbf{X}_{ik}) \quad \text{and} \quad h_{ik}(t|\theta_i) = \theta_i exp(\beta \mathbf{X}_{ik}) p t^{p-1}$$

The dependent variable in every case is the incidence of repurchase (coded as 1), with the time between each interval emphasising the hazard of a firm repurchasing. Vector **X** captures the model variables of options, firm size, investment opportunity, volatility, spread, lagged returns and dividend payout. Definition of main variables of interest used in the table, including controls, is provided in the Appendix (Table A1). θ captures the shared frailty of firms in both models, which controls for unobserved effects in interval groupings at a firm level. Model coefficients from the regressions are displayed, along with their respective t-statistics (in parentheses). Hazard rate for a standard deviation change in a variable is determined by exponentiating the product of a variable's coefficient and its standard deviation. The table also reports likelihood-ratio tests for frailty. Model chi2 and their respective p-values are also reported. *, ** and *** refer to a two-sided t-test representing 10%, 5% and 1% statistical significance.

	Cox PH		Weibull PH	
	(1)	(2)	(3)	(4)
Options	0.2982***		0.2133***	
	(15.15)		(12.23)	
Unvested options		0.3931***		0.5664***
		(10.35)		(14.60)
Vested options		0.2304***		0.0150
		(7.94)		(0.58)
Size	-0.0287	-0.0450	-0.2159***	-0.2560***
	(-0.78)	(-1.22)	(-6.54)	(-7.78)
Investment opportunity	0.1556***	0.1657***	0.0696***	0.1302***
	(5.26)	(5.50)	(3.65)	(6.16)
Volatility	0.2360	0.3683*	-1.7436***	-1.5202***
	(1.10)	(1.69)	(-9.87)	(-8.60)
Spread	0.1289***	0.1301***	0.1074***	0.1192***
	(10.51)	(10.73)	(10.08)	(11.47)
Lagged return	0.2740***	0.2891***	-0.4734***	-0.4515***
	(4.15)	(4.36)	(-8.13)	(-7.80)
Dividend payout	0.0198***	0.0199***	0.0174***	0.0179***
	(20.58)	(20.69)	(20.45)	(21.02)
Constant			-7.6515***	-7.5515***
			(-18.06)	(-17.67)
Frailty	Gamma	Gamma	Gamma	Gamma
LR test of frailty (θ=0)	0.0000	0.0000	0.0000	0.0000
Chi2	886.1156	896.7743	764.8401	869.4109
p-value	0.0000	0.0000	0.0000	0.0000
N	9,082	9,082	9,082	9,082

Table 8: Hazard model of dilutive option holdings on incremental repurchase days

This table shows the results for semi-parametric Cox proportional hazard-rate model using different number of consecutive repurchase days in each specification. The Cox model follows the following specification.

$$h_{ik}(t|\theta_i) = \theta_i h_0(t) exp(\beta \mathbf{X}_{ik})$$

The dependent variable in every case is the incidence of repurchase (coded as 1), with the time between each interval emphasising the hazard of a firm repurchasing. Vector **X** captures the model variables of options, firm size, investment opportunity, volatility, spread, lagged returns and dividend payout. Definition of main variables of interest used in the table, including controls, is provided in the Appendix (Table A1). θ captures the shared frailty of firms in both models, which controls for unobserved effects in interval groupings at a firm level. Each specification uses only the number of consecutive repurchase days indicated. Firms with fewer repurchase days get right-censored. Model coefficients from the regressions are displayed, along with their respective t-statistics (in parentheses). Hazard rate for a standard deviation change in a variable is determined by exponentiating the product of a variable's coefficient and its standard deviation. Panel A shows the results for option holdings, while panel B does the same based on vesting conditions. The table also reports likelihood-ratio tests for frailty. Model chi2 and their respective *p*-values are also reported. *, ** and *** refer to a two-sided t-test representing 10%, 5% and 1% statistical significance.

Panel A: Option holdings

	Event1	Event2	Event3	Event4	Event5
	(1)	(2)	(3)	(4)	(5)
Options	0.1094	0.2178	-0.3074	0.4312**	0.4306***
	(1.39)	(1.52)	(-1.34)	(2.11)	(2.96)
Size	0.2005***	0.5079***	0.3012	0.7122**	1.2664***
	(3.03)	(3.63)	(1.07)	(2.33)	(4.12)
Investment opportunity	0.7040***	0.8562**	-1.2275***	-0.9567**	-1.5897***
	(3.06)	(2.09)	(-3.01)	(-2.12)	(-4.83)
Volatility	0.4048	-0.1833	-3.3960	-6.2231***	-0.7234
	(0.39)	(-0.11)	(-1.59)	(-3.26)	(-0.42)
Spread	0.0049	0.0056	0.0330**	0.0173	0.0102
	(0.95)	(0.51)	(2.13)	(1.30)	(0.76)
Lagged return	-0.2819	-0.9854	0.7883	1.1256	0.1453
	(-0.87)	(-1.64)	(1.00)	(1.57)	(0.22)
Dividend payout	-0.7242	-1.3832	2.3024	5.3420	11.0184***
	(-0.69)	(-0.65)	(0.63)	(1.44)	(2.83)
Frailty	Gamma	Gamma	Gamma	Gamma	Gamma
LR test of frailty (θ=0)	0.0000	0.0000	0.0000	0.0000	0.0000
Chi2	18.3742	30.4936	32.5561	25.2837	53.6249
p-value	0.0104	0.0001	0.0000	0.0007	0.0000
N	101	171	234	292	345

Panel B: Option vestability

	Event1	Event2	Event3	Event4	Event5
	(1)	(2)	(3)	(4)	(5)
Unvested options	0.2747*	0.4322**	0.1637	0.7664**	1.2394***
	(1.71)	(2.08)	(0.60)	(2.51)	(4.51)
Vested options	0.0977	0.1675	-0.2376	-0.1134	0.3876*
	(1.09)	(1.11)	(-1.09)	(-0.49)	(1.94)
Size	0.1961***	0.3628***	0.2691	0.8063***	1.3818***
	(2.87)	(2.95)	(1.05)	(2.61)	(4.16)
Investment opportunity	0.6525***	0.8618**	-1.2264***	-1.2192***	-1.4949***
	(2.82)	(2.21)	(-3.10)	(-2.89)	(-3.79)
Volatility	0.5636	0.8422	0.3062	-4.0895**	1.6941
	(0.53)	(0.50)	(0.13)	(-2.14)	(0.93)
Spread	0.0058	0.0072	0.0643***	0.0305**	0.0412**
	(1.12)	(0.65)	(3.45)	(2.02)	(2.54)
Lagged return	-0.3625	-1.2772**	-0.4084	0.0133	-1.5622**
	(-1.13)	(-2.15)	(-0.44)	(0.02)	(-2.35)
Dividend payout	0.0053	0.0195**	0.0596***	0.0234*	0.0558***
	(1.05)	(2.17)	(3.60)	(1.90)	(4.87)
Frailty	Gamma	Gamma	Gamma	Gamma	Gamma
LR test of frailty (θ=0)	0.0000	0.0000	0.0000	0.0000	0.0000
Chi2	19.2080	31.7870	34.7371	28.1436	64.5273
p-value	0.0138	0.0001	0.0000	0.0004	0.0000
N	101	171	234	292	345

Table 9: Hazard model of dilutive option holdings of overconfident boards on repurchase continuity: HOL67

This table shows the results for parametric Weibull hazard-rate models using the following specification.

$$h_{ik}(t|\theta_i) = \theta_i exp(\beta \mathbf{X}_{ik}) p t^{p-1}$$

The dependent variable in every case is the incidence of repurchase (coded as 1), with the time between each interval emphasising the hazard of a firm repurchasing. Vector **X** captures the model variables of options, firm size, investment opportunity, volatility, spread, lagged returns and dividend payout. Definition of main variables of interest used in the table, including controls, is provided in the Appendix (Table A1). θ captures the shared frailty of firms in both models, which controls for unobserved effects in interval groupings at a firm level. We also incorporate an overconfident board indicator variable, *HOL67*, defined by Malmendier and Tate (2005, 2008) as a dummy of unity if executives hold on to vested options that are less than five years to expiry and are more than sixty-seven percent in-the-money. This variable is interacted with the option holdings variable in columns (1) and (2), and its segregated measures of vested and unvested stock options in columns (3) and (4). Model coefficients from the regressions are displayed, along with their respective t-statistics (in parentheses). Hazard rate for a standard deviation change in a variable is determined by exponentiating the product of a variable's coefficient and its standard deviation. The table also reports likelihood-ratio tests for frailty and proportional hazard. Model chi2 and their respective p-values are also reported. *, ** and *** refer to a two-sided t-test representing 10%, 5% and 1% statistical significance.

	Option holdings		Option vestability	
	(1)	(2)	(3)	(4)
HOL67	-0.8931***	-0.8394***	-0.8502***	-0.7342***
	(-6.46)	(-6.01)	(-6.14)	(-5.17)
Options	0.2231***	0.2772***		
	(12.78)	(11.94)		
Unvested options			0.5710***	0.6873***
			(14.70)	(12.06)
Vested options			0.0263	0.1048***
			(1.02)	(3.61)
HOL67 * Options		-0.1265***		
		(-3.64)		
HOL67 * Unvested options				-0.0362
				(-0.39)
HOL67 * Vested options				-0.3309***
				(-4.85)
Size	-0.2221***	-0.2258***	-0.2616***	-0.2690***
	(-6.68)	(-6.74)	(-7.90)	(-7.94)
Investment opportunity	0.0667***	0.0695***	0.1281***	0.1404***
	(3.47)	(3.63)	(6.03)	(6.27)
Volatility	-1.9025***	-1.8997***	-1.6749***	-1.6202***
	(-10.61)	(-10.63)	(-9.34)	(-9.08)
Spread	0.1100***	0.1032***	0.1236***	0.1153***
	(10.17)	(9.47)	(11.66)	(10.81)
Lagged return	-0.4881***	-0.4874***	-0.4663***	-0.4633***
	(-8.37)	(-8.32)	(-8.04)	(-7.91)
Dividend payout	0.0176***	0.0180***	0.0181***	0.0186***
	(20.71)	(20.95)	(21.26)	(21.57)
Constant	-7.0254***	-7.0343***	-6.9619***	-7.0274***
	(-15.39)	(-15.39)	(-15.16)	(-15.21)
Frailty	Gamma	Gamma	Gamma	Gamma
LR test of frailty (θ=0)	0.0000	0.0000	0.0000	0.0000
Chi2	803.3046	816.9770	904.2892	944.0758
p-value	0.0000	0.0000	0.0000	0.0000
PH test	0.0000	0.0000	0.0000	0.0000
N	9,082	9,082	9,082	9,082

Figure 1: Survival curve of repurchase intensity of overconfident boards

This figure illustrates the cumulative survival probability of firms undertaking repeated share buybacks. This survival probability is shown split by our measure of board overconfidence. We incorporate an overconfident board indicator variable, *HOL67*, defined by Malmendier and Tate (2005, 2008) as a dummy of unity if executives hold on to vested options that are less than five years to expiry and are more than sixty-seven percent in-the-money. The figure is illustrated in analysis time in the x-axis, indicating number of days it takes for the survival probability of firms repurchasing shares to go to 0. 95% confidence interval bounds are also shown for both groups of overconfident boards.

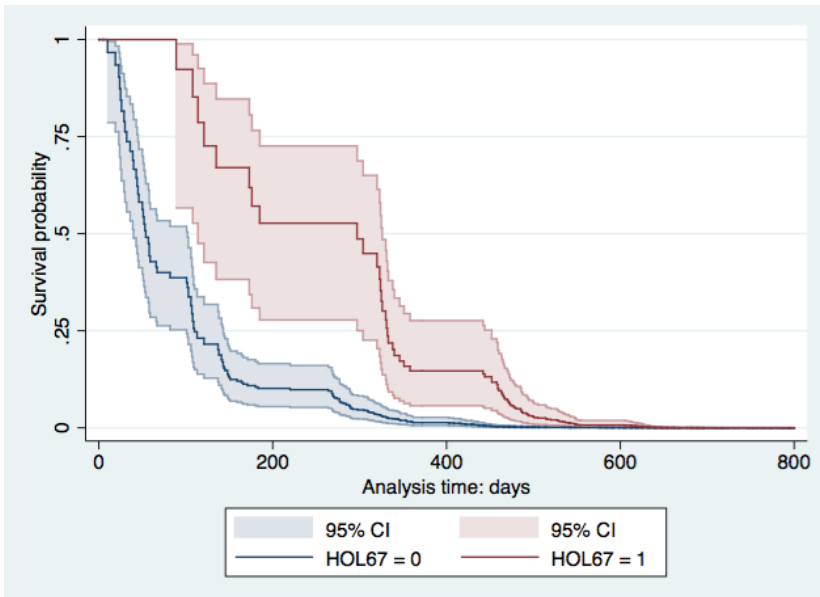
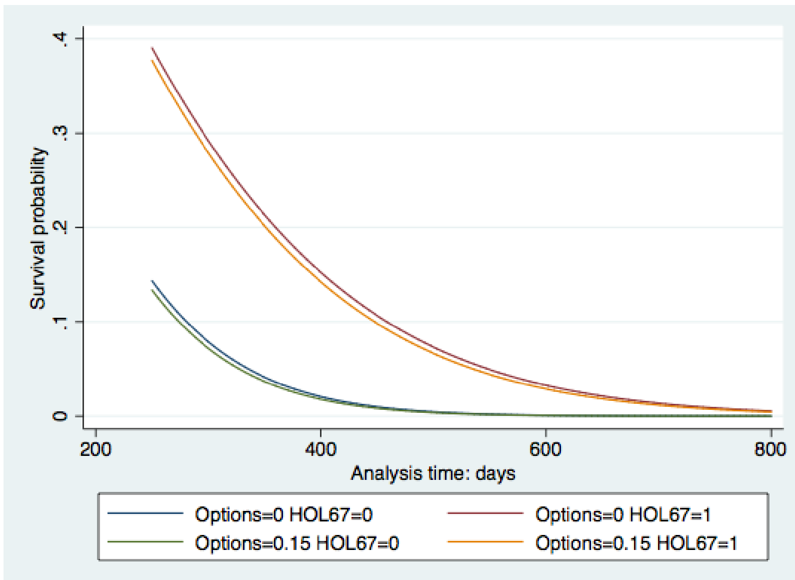


Figure 2: Survival curve of repurchase intensity of overconfident boards: option vestability

This figure illustrates the smoothed cumulative survival probability of firms undertaking repeated share buybacks. This survival probability is shown split by our measure of board overconfidence. We incorporate an overconfident board indicator variable, *HOL67*, defined by Malmendier and Tate (2005, 2008) as a dummy of unity if executives hold on to vested options that are less than five years to expiry and are more than sixty-seven percent in-the-money. Panel A shows the distribution for aggregate option holdings based on whether firms hold no options or sample median options of 0.15%. Similarly, panel B shows the same based on unvested and vested stock options, split by the overconfidence measure. The figures are illustrated in analysis time in the x-axis, indicating number of days it takes for the survival probability of firms repurchasing shares to go to zero.

Panel A: Smoothed cumulative survival probability of overconfident boards: option holdings



Panel B: Smoothed cumulative survival probability of overconfident boards: option vestability

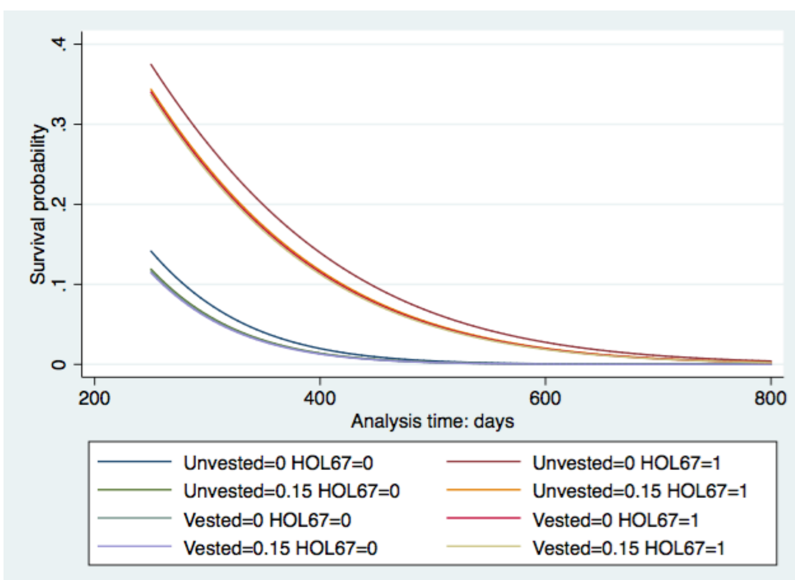


Table 10: Hazard model of dilutive option holdings of overconfident boards on repurchase continuity: LONGHOL

This table shows the results for parametric Weibull hazard-rate models using the following specification.

$$h_{ik}(t|\theta_i) = \theta_i exp(\beta \mathbf{X}_{ik}) p t^{p-1}$$

The dependent variable in every case is the incidence of repurchase (coded as 1), with the time between each interval emphasising the hazard of a firm repurchasing. Vector **X** captures the model variables of options, firm size, investment opportunity, volatility, spread, lagged returns and dividend payout. Definition of main variables of interest used in the table, including controls, is provided in the Appendix (Table A1). θ captures the shared frailty of firms in both models, which controls for unobserved effects in interval groupings at a firm level. We also incorporate an overconfident board indicator variable, *LONGHOL*, defined by Malmendier and Tate (2005, 2008) as a dummy of unity if executives hold on to vested options that are in their final year of expiry and are more than forty percent in-the-money. This variable is interacted with the option holdings variable in columns (1) and (2), and its segregated measures of vested and unvested stock options in columns (3) and (4). Model coefficients from the regressions are displayed, along with their respective t-statistics (in parentheses). Hazard rate for a standard deviation change in a variable is determined by exponentiating the product of a variable's coefficient and its standard deviation. The table also reports likelihood-ratio tests for frailty and proportional hazard. Model chi2 and their respective p-values are also reported. *, ** and *** refer to a two-sided t-test representing 10%, 5% and 1% statistical significance.

	Option holdings		Option vestability	
	(1)	(2)	(3)	(4)
LONGHOL	2.1576***	2.7827***	1.9714***	3.6223***
	(6.96)	(7.86)	(6.34)	(9.90)
Options	0.2158***	0.2229***		
	(12.37)	(12.74)		
Unvested options			0.5385***	0.5126***
			(13.90)	(13.16)
Vested options			0.0338	0.0610**
			(1.32)	(2.38)
LONGHOL * Options		-0.5417***		
		(-3.62)		
LONGHOL * Unvested options				1.5656***
				(5.24)
LONGHOL * Vested options				-2.3653***
				(-8.77)
Size	-0.2121***	-0.2170***	-0.2494***	-0.2341***
	(-6.43)	(-6.58)	(-7.58)	(-7.07)
Investment opportunity	0.0682***	0.0696***	0.1229***	0.1181***
	(3.57)	(3.64)	(5.85)	(5.67)
Volatility	-1.5547***	-1.6037***	-1.3718***	-1.3550***
	(-8.75)	(-8.99)	(-7.73)	(-7.59)
Spread	0.1051***	0.1051***	0.1165***	0.1150***
	(9.88)	(9.89)	(11.18)	(10.96)
Lagged return	-0.4637***	-0.4774***	-0.4453***	-0.4754***
	(-7.97)	(-8.16)	(-7.70)	(-8.15)
Dividend payout	0.0178***	0.0180***	0.0182***	0.0185***
	(20.87)	(21.01)	(21.34)	(21.59)
Constant	-8.0886***	-8.0674***	-7.9675***	-8.3050***
	(-19.22)	(-19.13)	(-18.75)	(-19.52)
Frailty	Gamma	Gamma	Gamma	Gamma
LR test of frailty (θ=0)	0.0000	0.0000	0.0000	0.0000
Chi2	849.4614	862.6479	936.3390	1023.7979
p-value	0.0000	0.0000	0.0000	0.0000
PH test	0.0000	0.0000	0.0000	0.0000
N	9,082	9,082	9,082	9,082

Table 11: Hazard model of dilutive option holdings on repurchase continuity: TREASURY

This table shows the results for parametric Weibull hazard-rate models using the following specification.

$$h_{ik}(t|\theta_i) = \theta_i exp(\beta \mathbf{X}_{ik}) pt^{p-1}$$

The dependent variable in every case is the incidence of repurchase (coded as 1), with the time between each interval emphasising the hazard of a firm repurchasing. Vector **X** captures the model variables of options, firm size, investment opportunity, volatility, spread, lagged returns and dividend payout. Definition of main variables of interest used in the table, including controls, is provided in the Appendix (Table A1). θ captures the shared frailty of firms in both models, which controls for unobserved effects in interval groupings at a firm level. We also incorporate an indicator variable, *TREASURY*, which takes the value of unity of repurchase transactions after after 2003, else null. This highlights the change in treasury shares regulation in the UK. This variable is interacted with the option holdings variable in columns (1) and (2), and its segregated measures of vested and unvested stock options in columns (3) and (4). Model coefficients from the regressions are displayed, along with their respective t-statistics (in parentheses). Hazard rate for a standard deviation change in a variable is determined by exponentiating the product of a variable's coefficient and its standard deviation. The table also reports likelihood-ratio tests for frailty and proportional hazard. Model chi2 and their respective *p*-values are also reported. *, ** and *** refer to a two-sided t-test representing 10%, 5% and 1% statistical significance.

	Option holdings		Option vestability	
	(1)	(2)	(3)	(4)
TREASURY	-1.3043***	-1.1999***	-1.2726***	-1.3515***
	(-36.25)	(-32.09)	(-35.12)	(-31.21)
Options	0.1931***	0.5791***		
	(11.26)	(14.12)		
Unvested options			0.4733***	-0.3844**
			(12.53)	(-2.36)
Vested options			0.0291	0.6862***
			(1.15)	(15.02)
TREASURY * Options		-0.4354***		
		(-10.35)		
TREASURY * Unvested options				1.0970***
				(6.62)
TREASURY * Vested options				-0.9774***
				(-18.06)
Size	-0.2482***	-0.1759***	-0.2855***	-0.1647***
	(-7.69)	(-5.14)	(-8.84)	(-4.62)
Investment opportunity	0.0729***	0.0492***	0.1227***	0.1390***
	(3.92)	(2.58)	(6.09)	(5.96)
Volatility	-3.8697***	-4.2866***	-3.6494***	-4.3811***
	(-19.58)	(-20.91)	(-18.41)	(-20.91)
Spread	0.0434***	0.0367***	0.0525***	0.0440***
	(5.30)	(4.60)	(6.05)	(5.26)
Lagged return	-0.4521***	-0.4151***	-0.4253***	-0.3214***
	(-7.83)	(-7.27)	(-7.38)	(-5.70)
Dividend payout	0.0161***	0.0163***	0.0165***	0.0155***
	(18.72)	(18.87)	(19.18)	(17.59)
Constant	-9.3547***	-9.8908***	-9.1942***	-10.0824***
	(-22.39)	(-23.62)	(-21.79)	(-23.92)
Frailty	Gamma	Gamma	Gamma	Gamma
LR test of frailty (θ=0)	0.0000	0.0000	0.0000	0.0000
Chi2	1542.0522	1654.1812	1608.0105	1995.2026
p-value	0.0000	0.0000	0.0000	0.0000
PH test	0.0000	0.0000	0.0000	0.0000
N	9,082	9,082	9,082	9,082

Table A1: Variable definitions

This table presents the description of variables used in the study. The computation of the explanatory variables is provided as the description, along with their respective Datastream/ Worldscope codes (in parentheses), where applicable.

Variables	Description
Continuity	Defined as the number of consecutive repurchase days scaled by 252. A dummy variable variant is also used taking the value of zero if number of consecutive repurchase days is two or more trading days, else unity.
Options	Based on data from BoardEx, it represents the total (exercisable and unexercisable) options outstanding, scaled by total shares outstanding.
Unvested options	A subset of option holdings, representing options that are unvested (unexercisable).
Vested options	A subset of option holdings, representing options that are vested (exercisable).
HOL67	Following Malmendier and Tate (2005, 2008), this dummy variable captures aggregate Board holdings of exercisable options that are at least 67% in-the-money and are less than 5 years away from expiry. A firm is classified as overconfident for the entire sample period if a Board is found to breach the conditions more than three times.
LONGHOL	Following Malmendier and Tate (2005, 2008), this dummy variable captures aggregate Board holdings of exercisable options that are at least 40% in-the-money and is held until expiry. A firm is classified as overconfident for the entire sample period if a Board is found to breach the conditions at least once.
TREASURY	Dummy variable takes the value of 1 if repurchase takes place after 1st December 2003, and 0 for all prior buybacks.
Return	Log-normalised value of the difference in contemporaneous and lagged value of return index (RI).
Market	Coefficient estimates of risk-adjusted market returns, based on data provided by Gregory et al. (2013).
SmallMinusBig	Coefficient estimates of portfolios of difference in small and big firms, based on data provided by Gregory et al. (2013).
HighMinusLow	Coefficient estimates of portfolios of difference in high and low investment opportunity firms, based on data provided by Gregory et al. (2013).
Momentum	Coefficient estimates of portfolios of returns driven by momentum, based on data provided by Gregory et al. (2013).
Size	Log-normalised value of total firm equity (MV).
Investment opportunity	Market-to-book ratio measured as market value (book value of debt: WC02999-WC03501, plus market value of equity: MV) scaled by book value of assets (DWTA) in 2011 terms.
Volatility	Computed as a 1-year lagged standard deviation of return index (RI).
Spread	Computed as an average 3-month lagged spread between ask (PA) and bid price (PB).
Lagged return	Log-normalised, 6-month rolling returns of return index (RI).
Dividend payout	Ratio of total dividends per share paid in a trailing 12-month period scaled by earnings per share (WC09504).